PROCEEDINGS OF THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

CONTENTS, VOLUME 76

(For detailed index, see Bulletin 653, page 725)

Bulletin 649, September–October 1974 Page

Decay and Termite Control Investigation—Final Inspection of Specimens After 180 Months Exposure—Long-Range Tests on Wood Preservation (Committee 3—Ties and Wood Preservation) 1
Tie Renewals and Costs (Committee 3—Ties and Wood Preservation) ... 55
Rail Research and Development (Committee 4—Rail):
  Part 1—Metallurgical Examination and Physical Tests Results of Chromium and Manganese-Vanadium Alloy Rail Steel Investigation 65
  Part 2—Summary of Performance of Standard-Carbon and Various Wear-Resistant Rails in Test Curves on the Chessie System 99
Continuing Education (Committee 24—Engineering Education) 125
Exchange of Professional Staffs (Committee 24—Engineering Education) .. 128
Economics of Freight Cars with Characteristics Approaching the Limits of Acceptable Designs (Committee 16—Economics of Plant, Equipment and Operations) 137

Bulletin 650, November–December 1974 (Part 1)

Manual Recommendations 145–245

Bulletin 650, November–December 1974 (Part 2—Reports of Committees)

Highways (9) 249
Engineering Records and Property Accounting (11) 259
Yards and Terminals (14) 267

Bulletin 651, January–February 1975 (Reports of Committees)

Roadway and Ballast (1) 279
Buildings (6) 299
Timber Structures (7) 315
Concrete Structures and Foundations (8) 319
Economics of Plant, Equipment and Operations (16) 325
Economics of Railway Construction and Maintenance (22) 327
Environmental Engineering (13) 341
Steel Structures (15) 351
Maintenance of Way Work Equipment (27) 353
Clearances (28) 361
Systems Engineering (32) 363
Engineering Education (24) 373
Electrical Energy Utilization 383
Rail (4) 405
Track (5) 409
Scales 415
Ties and Wood Preservation (3) 417

Bulletin 653, June–July 1975 (Technical Conference Report)

Page
President's Address 459
Special Features 463
Installation of Officers 645
AAR Engineering Division Session 649
Report of Executive Director 691
Report of Treasurer 703
AREA Constitution 709

American Railway Engineering Association—Bulletin

Bulletin 649
Proceedings Volume 76*

September–October 1974

CONTENTS

ADVANCE COMMITTEE REPORTS

Decay and Termite Control Investigation—Final Inspection of Specimens After 180 Months Exposure—Long-Range Tests on Wood Preservation (Committee 3—Ties and Wood Preservation) ---------- 1

Tie Renewals and Costs (Committee 3—Ties and Wood Preservation) ---------- 55

Rail Research and Development (Committee 4—Rail):

Part 1—Metallurgical Examination and Physical Tests Results of Chromium and Manganese–Vanadium Alloy Rail Steel Investigation ---------- 65

Part 2—Summary of Performance of Standard–Carbon and Various Wear-Resistant Rails in Test Curves on the Chessie System ---------- 99

Continuing Education (Committee 24—Engineering Education) ---------- 125

Exchange of Professional Staffs (Committee 24—Engineering Education) ---------- 128

Economics of Freight Cars with Characteristics Approaching the Limits of Acceptable Designs (Committee 16—Economics of Plant, Equipment and Operations) ---------- 137

Directory—Consulting Engineers ----------142–1

---

* Proceedings Volume 76 (1975) will consist of AREA Bulletins 649, September–October 1974; 650, November–December 1974; 651, January–February 1975; and 653, June–July 1975 (Technical Conference Report issue). Blue-covered Bulletin 652, April–May 1975 (the Directory issue), is not a part of the Annual Proceedings of the Association.

BOARD OF DIRECTION
1974–1975

President

R. F. Bush, Chief Engineer, Erie Lackawanna Railway, Midland Bldg., Cleveland, OH 44115

Vice Presidents

J. T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, 500 Water St., Jacksonville, FL 32202

W. J. Jones, Engineer Maintenance of Way and Structures, System, Southern Pacific Transportation Company, 1 Market St., San Francisco, CA 94105

Past Presidents

R. M. Brown, Chief Engineer, Union Pacific Railroad, 1416 Dodge St., Omaha, NE 68179

D. V. Sartore, Chief Engineer—Design, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101

Directors

B. G. Anderson, Assistant Vice President—Engineering, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101

John Fox, Assistant Chief Engineer, Canadian Pacific Rail, Windsor Station, Montreal, PQ H3C 3E4

C. E. Weller, Assistant Vice President—Engineering, Chicago, Rock Island & Pacific Railroad, LaSalle St. Station, Chicago, IL 60605

B. J. Gordon, Chief Engineering Officer, Penn Central Transportation Company, 6 Penn Center Plaza, Room 1640, Philadelphia, PA 19104

R. W. Pember, Chief Engineer, Design and Construction, Louisville & Nashville Railroad, P. O. Box 1198, Louisville, KY 40201

E. Q. Johnson, Senior Assistant Chief Engineer, Chessie System, P. O. Box 1800, Huntington, WV 25718

W. E. Fuhr, Assistant Chief Engineer—Staff, Chicago, Milwaukee, St. Paul & Pacific Railroad, Union Station, Room 898, Chicago, IL 60606

B. E. Pearson, Chief Engineer, Soo Line Railroad, Soo Line Bldg., Room 1520, Minneapolis, MN 55440

P. L. Montgomery, Manager Engineering Systems, Norfolk & Western Railway, 8 N. Jefferson St., Roanoke, VA 24011

E. C. Honath, Assistant General Manager Engineering, Western Lines, Atchison, Topeka & Santa Fe Railway, 900 Polk St., Amarillo, TX 79101

Mike Rougas, Chief Engineer, Bessemer & Lake Erie Railroad, P. O. Box 471, Greenville, PA 16125

J. W. DeValle, Chief Engineer Bridges, Southern Railway System, 99 Spring St., S. W., Atlanta, GA 30303

Treasurer

A. B. Hillman, Jr., Chief Engineer, Belt Railway of Chicago, 6900 S. Central Ave., Chicago, IL 60638

Executive Director

Earl W. Hodgkins, 59 E. Van Buren St., Chicago, IL 60605

Assistant to Executive Director

N. V. Engman, 59 E. Van Buren St., Chicago, IL 60605

Administrative Assistant

D. F. Fredley, 59 E. Van Buren St., Chicago, IL 60605

Published by the American Railway Engineering Association, Bi-Monthly, January–February, April–May, June–July, September–October and November–December, at
59 East Van Buren Street, Chicago, Ill. 60605

Second class postage at Chicago, Ill., and at additional mailing offices.
Subscription $15 per annum.

Copyright © 1974
by the
American Railway Engineering Association
All rights reserved.

No part of this publication may be reproduced, stored in an information or data retrieval system, or transmitted, in any form, or by any means—electronic, mechanical, photocopying, recording, or otherwise—without the prior written permission of the publisher.

Advance Report of Committee 3—Ties and Wood Preservation

G. H. Way, *Chairman*

Your committee presents below, as information, Association of American Railroads Research and Test Department Report No. R-148 (Project No. R030), "Decay and Termite Control Investigation—Final Inspection of Specimens after 180 Months of Exposure—Results of Long-Range Tests on Wood Preservation." The author of the report is Cornel Somogy, assistant research engineer, AAR Technical Center, Chicago.

DECAY AND TERMITE CONTROL INVESTIGATION—FINAL INSPECTION OF SPECIMENS AFTER 180 MONTHS EXPOSURE—RESULTS OF LONG-RANGE TESTS ON WOOD PRESERVATION

CORNEL SOMOGY

Abstract

A 15-year investigation was initiated in 1957 in order to determine the long-range effects of termite attack and decay on wood as well as to evaluate the protective effects of various commercial preservatives of various retentions towards the reduction of termite attack and decay.

The changes were observed and recorded annually of nearly 2000 test specimens which reflected all the significant test variables of species of wood and type and retention of preservative. The results of these recorded observations have been analyzed and evaluated and conclusions derived, which are as follows:

1. Decay occurred to a greater extent and generally progressed faster than termite damage.
2. The results of this investigation indicated that coal tar creosote and the solution of creosote with coal tar or petroleum are the most effective preservatives; chromated zinc chloride and fluor-chrome-arsenate-phenol—type A afford the least protection against decay and termite attack.
3. The protection (as reflected in the average index rating) increases with the retention of the preservative in the specimens.
4. Untreated oak is somewhat more resistant to decay and termite attack than fir or pine, but only for a short time.
5. The results of this control test show that the life span of wood, when exposed to decay and termite attack environments, can be increased considerably by the application of the proper type and amount of preservative.

Introduction

This report presents the final results of a termite control investigation, initiated by AREA Committee 3—Ties and Wood Preservation. The investigation consisted of a series of tests conducted in the exposure test plot of the Austin Cary Memorial Forest of the University of Florida, Gainesville, Florida. The exposure lasted a total of 180 months. Inspections were repeated regularly in one-year intervals to record both decay and termite attack on the test material and to subsequently determine how various preservatives controlled the deterioration.

ACKNOWLEDGMENT

The investigation was sponsored by the AREA. The costs involved were paid by the AAR. The project was under the general direction of G. M. Magee, former director of engineering research (now retired), and under the immediate supervision of E. J. Ruble, former executive research engineer (now retired).

The U. S. Forest Products Laboratory in Madison, Wisconsin, conducted the chemical analysis of the preservatives and the treatment of the test specimens. J. O. Blew of the Forest Products Laboratory and Dr. J. B. Huffman of the University of Florida extended invaluable help both in the preliminary work of organizing the project and in collecting and evaluating the test data, and their assistance was greatly appreciated.

Previous inspections were conducted under the general direction of Mr. Ruble.

After regular annual inspections interim reports were released every year. The final inspection of the specimens was conducted on November 14 and 15, 1972, by Dr. Huffman; Mr. Magee; F. J. Fudge, timber engineer, Penn Central Transportation Co., and chairman, Subcommittee B of AREA Committee 3; K. C. Edscorn, purchasing agent, Missouri Pacific Railroad, and chairman, Subcommittee 5 of AREA Committee 3; and J. K. Gloster, assistant to vice president–engineering, Louisville & Nashville Railroad (now retired), and a member of AREA Committee 3.

1. HISTORICAL BACKGROUND

Wood is a structural material extensively used in the railroad industry, to a large extent as the material of cross and switch ties and also in construction of trestles, bridges and other permanent structures.

Great attention has been paid to the preservation and protection of wood against the two most common enemies of wood—termites and decay. Some chemicals have been found which successfully prevented damage from one or both sources and over considerable periods of time, and some research was applied to find the best and most economical ways of protection. This research from the beginning of the century to the late forties, under the sponsorship of railroad companies, ad hoc committees, and some research laboratories, yielded little conclusive information on controlled exposure over long time periods.

The investigation covered in this final report was initiated by AREA Committee 17—Wood Preservation, later, Committee 3—Ties and Wood Preservation, and was carried out with the cooperation of the AAR Technical Center, the Forest Products Laboratory, Madison, Wisconsin; and the Institute of Food and Agricultural Sciences, School of Forestry, of the University of Florida, Gainesville, Florida. Test procedures set forth in ASTM Specifications D 1758–60—Evaluating Wood Preservatives by Field Tests with Stakes, served as a guide, but in certain instances deviations occurred, in which cases they are noted in Appendix A.

The report describing the initial installation of treated specimens and untreated control specimens placed in the exposure test plot in November 1957 is published in the 1959 AREA Proceedings, Vol. 60, page 131. This detailed report covers the treatment of the specimens, chemical analysis of the preservatives and installation of the 1296 treated specimens and 30 untreated controls. A total of nine different preservatives were used to treat the oak, pine and fir specimens, using three different retentions for each preservative.

A supplemental installation involving the use of four additional preservatives was made in November 1959. A detailed report covering this installation of 576 treated specimens and 15 untreated controls is published in the 1961 AREA Proceedings, Vol. 62, page 95.

Detailed reports covering the inspection of the specimens after approximately 12-month intervals throughout the complete 15-year period were published in the AREA Proceedings and in Engineering Reports of the AAR Research Center.

The conclusions that could be drawn after the corresponding time of exposure were included in all reports.

The following table shows the complete documentation of the termite control investigation in chronological order:

REVIEW OF DOCUMENTATION ON THE PROGRESS OF TERMITE CONTROL INVESTIGATION

Published After Number of Months of Exposure	*Published in AREA Proceedings* Vol.	Page	*Published Engineering Reports of AAR*
Immediately after installation.	60	131	....
After additional installation.	62	95	....
40 months	63	53	ER-16
52 months	64	19	ER-23
64 months	65	253	ER-38
76 months	66	229	ER-46
88 months	67	184	ER-59
100 months	68	13	ER-66
112 months	69	1	ER-73
124 months	70	50	ER-84
148 months	..	..	LT-250
180 months	..	..	R-148

2. LOCATION AND INSTALLATION

The test site for this investigation was selected by the School of Forestry of the University of Florida. It is a rectangular plot with an area of about 1½ acres, but expandable for eventual later tests—about 13 miles from Gainesville, Florida. The site is part of the Austin Cary Memorial Forest owned and controlled by the University of Florida. Supervision was available all year around. The site is a typical longleaf pine flatwoods area covered with moderate vegetation; the soil is a Leon fine sand. The area drains well with ample periods of moisture, and is considerably infested by termites and decay producing fungi. (See Figs. 1a and 1b for location and field layout of test area.)

The area was initially divided into ten rectangular plots—each plot containing 15 rows extending from west to east and nine columns north to south. The constant spacing between columns was 3 ft, and between rows 4 ft. The rows were lettered in alphabetical order with capital letters from A to O; the columns were numbered, starting with 1 up to 9. As the program expanded, five more plots were established, and the plots increased to 11 columns, the last two bearing numbers

10 and 10A. At every intersection of a row and a column a 2 x 4-in hole 9 in deep was formed using a tree-planting tool in order not to disturb the soil. The test specimens, randomly distributed, were then placed in the holes, an identification tag placed on the north side, and the soil tamped around them by foot.

The test program originally called for 16 specimens, each of three kinds of wood with nine different preservatives of three different retentions, for a total of 81 combinations of test variables equal to 1296 specimens plus 10 untreated specimens of each species of wood. Installation of the above was the start of the project which later was extended with the investigation of four more solutions of chemical preservatives starting in November of 1959 and comprising an additional 576 treated specimens and five untreated specimens of each species of wood.

3. TEST SPECIMENS

The three species of wood selected for the test specimens were those most frequently used by the railroad industry—red oak, coast type Douglas fir and southern yellow pine and were given identification letters O, F and P respectively. All specimens were seasoned to an air-dry condition, cut to 1⅝- x 3⅝- x 18-in dimensions from commercially available standard 16-ft-long 2- x 4-in boards and furnished with an identification number. The groups of various species were treated with one of the following nine preservatives:

1. Coal tar creosote
2. Chromated zinc chloride
3. Fluor-chrome-arsenate-phenol—Type A
4. Pentachlorophenol
5. Copper naphthenate
6. Acid copper chromate
7. Ammonical copper arsenite
8. Chromated zinc arsenate
9. Chromated copper arsenate

The preservatives used in this investigation were furnished at no charge by the leading manufacturers of the country except in a few cases, when it was more convenient to purchase the needed quantities (copper naphthenate, acid copper chromate). Samples of these preservatives were chemically analyzed at the Forest Products Laboratory and the results of this analysis, compared with the AREA Specification requirements, are shown in the first section of Appendix A of this report. Typical records of treatment—excerpts from the treatment schedule of the Forest Products Laboratory—are also shown in the second part, Appendix B.

For each preservative there is an AREA specified recommended retention, varying from 0.5 to 8.0 lb per cu ft (see Appendix A, p. 35.). In this investigation, for each preservative, three different retentions were considered—the AREA-recommended (100%), half the AREA-recommended (50%), and twice the AREA-recommended (200%)—adding up to a total of 27 combinations of test variables.

Chemical formulations have been subject to changes throughout the past years. The preservatives used in this investigation were among those available in 1957. (See Appendix A of this report. Consult current AREA-recommended practices for preservatives.)

The treatment was carried out by the Forest Products Laboratory; 27 groups (bundles) containing 48 specimens each, a total of 1296 specimens, were delivered to the test site and distributed among the plots. Care was taken to obtain a random distribution of each species, preservative and retention throughout all the 10 plots to insure impartial and uniform exposure to the damaging factors, and to avoid unilateral influence of origin of the specimen, soil, environment or other local effect. Fig. 1c shows, as an example, the distribution in Plot 1.

In the 1959 extension of the investigation, five more plots were installed with similar species of wood, but treated with different preservatives. The preservatives numbered in consecutive order were solutions of:

10. 60 percent creosote with 40 percent coal tar,
11. 80 percent creosote with 20 percent coal tar,
12. 50 percent creosote with 50 percent petroleum,
13. 25 percent creosote with 75 percent petroleum,

again in three retentions. The retention of 50 percent AREA recommendation was labeled 1, the 100 percent retention 2, and the 200 percent retention 3.

A detailed record of the preservative treatment, retention and location of each test specimen was prepared and kept on file for all the inspections during the 15-year test period.

To illustrate this, Table 1 is shown as an example. Evident from this: e.g., in Plot 2, Row M, Position (Column) 4 is occupied by specimen O12D/21. The letter "O" designates oak species, "12" the stake number, "D" the fourth specimen cut, "2" the preservative number (chromated zinc chloride), and the last "1" indicates 50 percent retention. Along this line to the right are recorded the annual gradings for this specimen as outlined in the following section.

4. GRADING

The system of specimen grading for both decay and termite attack used during the inspection corresponds to that recommended by the American Wood-Preservers' Association. The code numbers and letters of the system are listed as follows with the corresponding ratings developed by such grades:

Code No.	*Decay Grades*	*Rating Percent*
1	Sound, no evidence of decay.	100
2	Localized superficial decay.	75
3	Slight but positive decay.	50
4	Deep or severe decay.	25
5	Failure, almost complete loss of strength.	0

Code Letter	*Termite Attack Grades*	*Rating Percent*
A	No attack.	100
B	Slight termite attack.	75
C	Moderate termite attack.	50
D	Severe termite attack.	25
E	Failure caused by termites.	0

Among wood preservation researchers it is generally agreed that when the quality index rating of a given set of test stakes reaches 40 or less, the wood at this stage of deterioration will, for practical purposes, be considered as having failed and would have to be replaced. The conditions of this test are most severe and in actual cases where treated wood is used, other measures (proper design, paint, etc.) are often employed to extend the useful life of the structural member beyond that which is attained in an accelerated test. Also, some preservative treatment is designed for ground contact while others are designed for wood used without ground contact, e.g., among preservatives listed above, Nos. 2, 3, 5, 6, and 8 are not intended for use in ground contact of structural members.

5. Field Inspection

The detailed inspection of the specimens was conducted by removing, grading and replacing the test specimens. All grading was performed by the same individual.

An example of the tabulated decay and termite attack grades, as recorded in the field on the "Field Inspection Data Sheets," is also shown on Table 1. The example shows the results of nine field inspections of the specimens in rows M, N and O of plot 2. The data secured during the first inspections, i.e., before 1962, are not included, since the initial deterioration was slow. Referring to above example, in position 4 of Row M, there is shown specimen O12D/21. As explained earlier, the letter "O" designated oak species, "12" the stick number and "D" the fourth specimen cut from stick 12. The figure "2" designates the preservative number, which in this case is chromated zinc chloride. The figure "1" represents the retention used in the treatment, and in this case is the lowest retention. The inspection of February 3, 1964, indicates this specimen had a grade of "5C", the "5" indicating failure due to decay with the "C" indicating moderate termite attack; consequently, the specimen was discarded and assumed to have a rating of "5E" for all inspections thereafter. As another example, there is shown in Table 1, Row O, Position 2, the pine specimen P1O1C/11 treated with the first or lowest amount of creosote. All inspections previous to the inspection of February 15, 1966, indicated that while there was no decay, there was evidence of some slight termite attack which resulted in a rating of "1B" as shown. The inspection of January 1967 did not indicate any termite attack, so the specimen was again rated as "1A" as shown; however, the inspection of February 8, 1968, indicated localized superficial decay and slight termite attack so the specimen was rated "2B" as shown. This rating did not change until November 14, 1972, when the final condition was rated "3C."

A close inspection of the Field Inspection Data Sheets indicates that some specimens were graded higher during a later inspection than during an earlier inspection, particularly with respect to termite attack; for example, see Row N, Position 2. In 1965 the specimen O61B/83 was graded as "3B," but in 1966 the grading was "3A," and in 1967 the grading was "5A" indicating failure due to decay but no termite attack. In general, upgrading from one year to the next year results from the destruction of physical evidence of former termite attack by the progression of decay fungi. Similarly, in some cases physical evidence of former decay might have been destroyed by more recent termite attack. Some difficulty was encountered during inspections in determining whether or not the insect galleries in decayed portions of the specimens were caused by termites or ants. If the termites or ants were present during the inspection a decision would readily be made, but if they were not present, and the usual tell-tale signs were not indicated, the cause of the galleries could not be definitely determined. Research has shown that ants frequently seek shelter or build nests in decayed wood while termites will drill through decayed wood to get to sound wood.

6. ANALYSIS OF FIELD INSPECTION DATA

The data on the decay and termite attack grades, as recorded on the Field Inspection Data Sheets, were summarized and recorded on the Classified Data Sheets, example of which is shown on Table 2. The ratings for both decay and termite attack, in percent, were determined in the manner shown under "Grading."

In the 12-, 25- and 40-month reports, the average index rating was obtained by averaging the decay rating with the termite attack rating. This procedure was slightly in variance with the recommendation of ASTM Specification D 1758–60, Evaluating Wood Preservatives by Field Data. The ASTM recommendation states that the decay and termite grades be combined, that is, the lowest grade from either cause be used, and therefore all subsequent average index ratings for the annual inspections were in accordance with the ASTM.

The data on Table 2 shows the results of the inspection of all specimens treated with preservative No. 2, chromated zinc chloride, having a No. 1 retention. It can be seen that previously mentioned specimen O12D/21 is included under the oak species, the second from the top, with a grade of "5C" assigned to it during the inspection of February 1964 and "5E" complete failure thereafter. The other nine specimens of like species and preservative retention are also shown accompanied by their respective grade. A summary of the grades for this preservative retention and species for the February 8, 1968, inspection is as follows:

9 specimens having a grade of "5" or "E" (complete failure)
1 specimen having a grade of "3C"
—
10 specimens

The ratings for decay and termite attack were obtained in the following manner.

Decay	*Termite Attack*
Nine (5) at 0 = 0	Nine (E) at 0 = 0
One (3) at 50 = 50	One (C) at 50 = 50
—	—
50 ÷ 10 = 5.0	50 ÷ 10 = 5.0

The average index rating was obtained by combining the decay and termite grades, using the lowest grade for each in the following manner:

Nine (5 or E) at 0 = 0
One (3 or C) at 50 = 50
—
50 ÷ 10 = 5.0

A summary of the grades for the No. 1 retention of chromated zinc chloride and the fir species for the inspection of February 8, 1968, is as follows:

Decay

Two (5) at 0 = 0
One (4) at 25 = 25
Seven (3) at 50 = 350
375 ÷ 10 = 37.5

Termite Attack

One (E) at 0 = 0
One (D) at 25 = 25
Eight (C) at 50 = 400
425 ÷ 10 = 42.5

The average index rating is then:

Two (5 or E) at 0 = 0
One (4 or D) at 25 = 25
Seven (3 or C) at 50 = 350
375 ÷ 10 = 37.5

Of course, after 1968 further rapid deterioration is evident from Table 2.

7. RESULTS OF INSPECTION

Untreated Controls

The decay and termite attack ratings with their average index ratings for the untreated controls installed in February 1964 are shown in Table 3. The values shown in this table are the average of five oak, five fir and five pine specimens, and indicate the general decline in the condition of the specimens over a period of four years, with most of the specimens completely failed after three years, and all but one fir specimen failed after four years.

The data for the untreated specimens installed in February 1965 are shown in Table 4. It can be seen that the rapid rate of termite attack and decay has continued through the third year. The average index ratings after 36 months exposure are slightly higher than the ratings for the specimens installed in February 1964 at the end of 36 months, due principally to the slow rate in the decline of the oak specimens. It can be seen that during the first year the oak specimens declined at a normal rate, but they did not change much during the next two years. Due to complete failure in six and five years, respectively, the tabulation is not continued beyond this point.

The data for the untreated specimens installed in February 1966 are further examples shown in Table 5 while the data for the specimens installed in February 1967 are shown in Table 6. It is interesting to note that the termite attack and decay are following the same pattern as the other installations after the same number of months exposure and that several specimens failed after 24 months exposure.

Treated Specimens

The decay and termite attack ratings after 180 months exposure of the specimens treated with preservatives 1 to 9, incl., and after 156 months exposure of specimens treated with preservatives 10 to 13, incl., are tabulated in Table 7.

The data tabulated in Table 7 for the specimens treated with the No. 1 retention are shown graphically by the bar diagram on Fig. 2, those for the retention No. 2 on Fig. 3, and those for the No. 3 retention on Fig. 4. In studying Figs. 2, 3 and 4, it should be kept in mind that the No. 1 retention is only half that recommended by the AREA. Retention No. 2 is the amount recommended, while retention No. 3 is twice the recommended amount. The bar diagrams indicate the following:

a. Retention No. 1—50% of the AREA recommended

Both decay and termite attack did take place in specimens of all three species treated with one of the 13 preservatives; however, decay appears to have been more rapid than termite attack. In this investigation, the rate of decay and termite attack was lower in the fir species than in the oak or pine species. The oak and pine species treated with either chromated zinc chloride or fluor-chrome-arsenate-phenol—Type A did fail.

b. Retention No. 2—100% AREA recommended

Decay did occur in all three species treated with one of the nine preservatives with termite attack in most of the species after 180 months exposure. Decay was present in all oak specimens treated with the creosote coal tar or creosote petroleum preservatives after 156 months exposure.

c. Retention No. 3—200% of the AREA recommended

Decay was taking place in the oak species treated with one of the 13 preservatives, and in some of the fir and pine species even though the retention is twice the recommended retention for that particular preservative. In general, the rate of decay was more rapid than the termite attack.

8. Discussion—Interpretation of Results

A study of the quality index ratings, as shown on Figs. 2, 3 and 4, clearly indicates that the oak specimens were generally more subject to decay than the fir or pine specimens for all preservatives and all retentions.

The diagrams on Figs. 5 to 13, incl., show the progressive decrease in the quality index ratings for all three species of wood, and the three retentions of all 13 preservatives. The original test specimens treated with the nine preservatives were exposed for 180 months while the specimens treated with the combinations of creosote and coal tar or petroleum were exposed for 156 months. It can be seen from Fig. 5 that the oak specimens treated with the No. 1 retention of creosote resisted decay and termite attack for 52 months, but since that time there was a gradual decrease in the rating, which seems to level out at 50 percent. For comparison, the oak specimens treated with fluor-chrome-arsenate-phenol—Type A completely failed after 100 months exposure, and the oak specimens treated with chromated zinc chloride failed after 148 months. It is obvious from the diagram on Fig. 5 that the oak specimens treated with the No. 1 retention of creosote have shown more resistance to decay and termite attack in the past than those treated with the other preservatives, but after 180 months the rating is close to that of pentachlorophenol, copper naphthenate and ammoniacal copper arsenite.

The decline in the quality index ratings of the fir specimens treated with the No. 1 retentions is shown on Fig. 6. It can be seen that the specimens treated with creosote or ammoniacal copper arsenite showed considerable resistance to decay and termite attack, but the ratings of the specimens treated with the other preservatives are only slightly higher than those for the oak specimens.

The decrease in ratings for the pine specimens treated with the No. 1 retentions is shown on Fig. 7. In general, these specimens have about the same ratings as the oak specimens. The specimens treated with preservative 10 (60 percent creosote and 40 percent coal tar) indicate a higher index rating than those treated with preservative 1 (coal tar creosote), but the coal tar creosote specimens were subjected to 25 more months exposure.

Similarly, the decrease in the quality index ratings for the other retentions of preservatives are shown on Figs. 8 to 13, incl. It can be seen that there is some reduction in the ratings of the specimens treated with most of the preservatives; however, the rate of deterioration is proportionately slower, as the amount of retention increased.

In order to illustrate the effect of varying the amount of preservative retention on the index rating, the diagrams on Fig. 14 indicate the effect for each of the nine preservatives after 180 months exposure. It appears from these diagrams that specimens treated with the AREA-recommended retention of coal tar creosote (1) and copper naphthenate (5) were the only preservatives which reached or exceeded 80 percent index rating for the fir species. To attain the same or better protection for the pine species, it was necessary to use 2 times the 1957 AREA-recommended retention. With this retention chromated copper arsenate (9) also gave slightly more than 80 percent index rating, i.e., protection. But for the oak species chromated copper arsenate (9) proved to be the only preservative and only in the strongest retention that yielded an average index rating equivalent to or more than 80 percent.

In order to compare solutions of creosote and coal tar or petroleum, respectively, average index ratings of the latter were calculated after maximum length of exposure, which was 156 months, since specimens treated with these mixtures were placed in the test plot later. Also, average index ratings were calculated for the original coal tar creosote specimens, but not to the full 180 months exposure; only for 148 months which was the closest exposure period to the above 156 months.

A comparison of the average Quality Index Ratings between the specimens treated with coal tar creosote (1) after 148 months exposure and combinations of creosote with petroleum or coal tar after 156 months exposure for all three species of wood and all three retentions is shown on Table 8. It can be seen that, in general, coal tar creosote is offering more protection than the other combinations only for the oak species and more so when the retention is stronger, i.e., retention 3, while this better protection decreases at retention 2 and even more at retention 1. For fir and pine species, however, some of the mixtures of creosote and coal tar or petroleum seem to be more effective and more so in lower concentrations.

A uniform measure to compare and quantify the protection of various preservatives or the deterioration of specimens suffered against that protection is to calculate the average percentage of deterioration per month. This is tabulated on Table 9. If the damage (according to the Average Rating) was 100 percent, this value has been divided by the number of months, after which period of time the complete damage was recorded. If, after 180 months of exposure the damage was not complete, the proper percentage has been divided by 180. In either case we obtained for every preservative, retention and species the average deterioration in percents per months, which corresponds to the average slope of the graph line on Figs. 5 to 13.

On Table 9 these percents of deterioration were further averaged, once according to preservatives and once again according to species and amounts of retention.

The two digits after the decimal point are the result of the computation; they do not necessarily reflect the accuracy with which the various test variables can be compared, let alone the useful life expectancy of the wood be predicted.

The value 1.0 means one percent of deterioration per month, i.e., a life expectancy of 100 months or 8⅓ years. If the specimen happened to last just 180 months, the percent was 100/180 = 0.56.

It is evident from Table 9 that among the various preservatives, coal tar creosote and creosote solutions are the more effective ones, resulting in deterioration as low as 0.15–0.16 percent per month or about 50–55 years of life expectancy.

The amount of retention is almost proportional to the expected protection, i.e., to the theoretical life expectancy.

Retention	*Amount*	*Average Deterioration Percent per Month*	*Approx. Life Expect. Years*
1	0.5 x AREA-recommended	0.41	20
2	1 x AREA-recommended	0.27	31
3	2 x AREA-recommended	0.14	60

Among the species, fir rates the highest (lowest percent per month) with oak second, and pine third at retention 1, but pine second and oak third at retention 2 and retention 3.

9. Conclusions

1. Decay is the greater danger to both untreated and treated specimens; decay occurs sooner than or simultaneously with termite attack; and its progress is faster than termite damage (Tables 3–6, Figs. 2–4).

2. Untreated specimens last generally no longer than 48 to 60 months, whatever the species; untreated oak, however, is generally more resistant to decay and termite attack during this time span than pine or fir (Tables 3–6).

3. Every preservative gives some protection against both decay and termite attack. No preservative shows positively better protection against decay or against termite attack (Table 7).

4. Among the preservatives tested and in order of their tabular sequence the following:

1. Coal tar creosote
4. Pentachlorophenol
5. Copper naphthenate
7. Ammoniacal copper arsenite

are the more effective. In comparison in order of their tabular sequence, the following:

9. Chromated copper arsenate
8. Chromated zinc arsenate
6. Acid copper chromate
3. Fluor-chrome-arsenate-phenol—Type A
2. Chromated zinc chloride

are the less effective preservatives.

Creosote, when mixed with coal tar or petroleum, had, in this investigation, protective properties comparable to coal tar creosote. Effectiveness is in the following order:

10. 60% creosote 40% coal tar
11. 80% creosote 20% coal tar
12. 50% creosote 50% petroleum
13. 25% creosote 75% petroleum

(See Figs. 2–13.)

5. The average index rating, as a measure of good protection, increases with the amount of preservative in the specimens. Changing the amount of preservative from retention 1 to retention 2 has a lesser effect on oak species than on fir or pine; the change from retention 2 to retention 3 has a rapid improving effect, on oak only, while on pine this effect diminishes and on fir stays fairly stable (Fig. 14).

6. The combination of best natural wood and best preservatives in this test site can extend the life span considerably. While untreated wood lasts about 2–3 years according to this test, effective treatment with preservatives may prolong this period up to about 10 times, i.e., to 20–30 years (Table 9).

LOCATION AND DETAIL OF TEST AREA

FIG. Ia

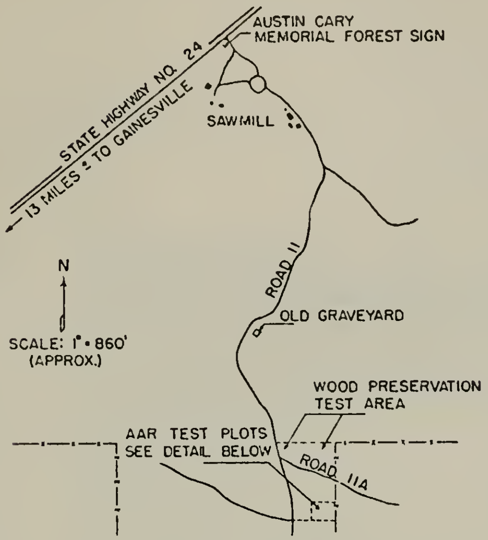
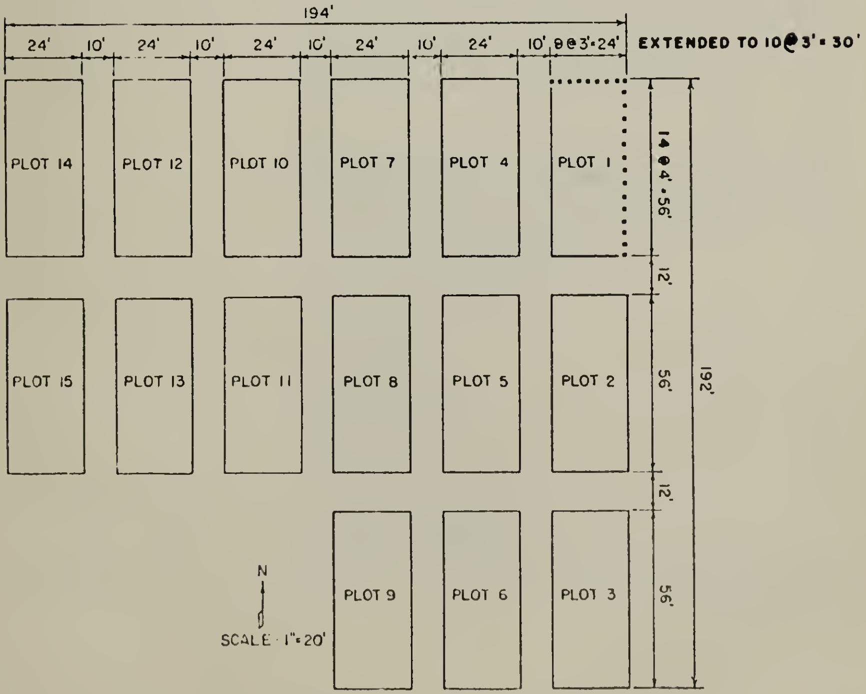
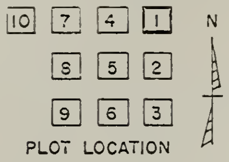


FIG. Ib



DETAIL OF PLOT LOCATION

▪ TEST SPECIMENS PLACED AS SHOWN



PLOT LOCATION

FIG. 1c

LOCATION OF SPECIMENS

PLOT 1

	1	2	3	4	5	6	7	8	9	10	10 A
A	049B [illegible]	P51B ● 72	P38C ● 92	F25I 81	015D ● 21	052G ● Control	P59D 81	P32I 21	P5B 82	P89A ● 1-2-59	P63C ● 1-30-67
B	P39B 53	F30A 83	043E 83	057C 51	F4C 43	F39H 71	F110E 13	F33C 93	F100A 32	018E ● 1-8-59	BLUE 1 1-30-67
C	F44F ● 61	040D 23	027H ● 31	F100D 52	F33E 63	P73B 42	F68B 62	P18A 22	077G 52	F6A ● 1-8-59	01A2 2-8-69
D	P10H 43	063G 32	F47B 52	F42B 73	F96B 12	P9B 51	093G 42	070H 13	F4I 41	P57-B ● 2-6-62	
E	07F 52	P81A 13	P94H 11	095A 42	F92G 53	08I 33	F95D 62	F24E 71	09E 33	F2381 ● 11-11-59	
F	P53H 63	P60A 63	P7C ● 61	0100F 72	040G ● 21	035G 53	F20B 72	F4H 42	P67H 13	027A1 ● 11-11-59	
G	055C 71	P10B 22	0106F 71	095I 82	F71B 22	051A 93	P32H ● Control	F100B ● 31	F101A 32	P5E ● 2-22-61	
H	041B 23	0103C 73	P110B ● 73	P44G 62	F43A 92	078B 13	041G ● 61	025I ● 81	P20G ● 31	F35B ● 2-22-61	
I	P94B 71	F41B ● 81	078D 41	P70C 33	F111E 33	P16B 61	P42A 72	F10E 11	041C 91	0106A ● 2-22-61	
J	[illegible]	F105G 33	F17E 13	F84A 91	015I 62	F19D 12	F88A 31	P109E 91	016D 11	J19 6-7-61	
K	[illegible]	P10H 53	019B 93	0101E 73	P105A 83	F33G 21	F57I 23	P54B 93	P102C 43	J20 ● 6-7-61	
L	[illegible] 82	F35I 23	P1A 52	P59C 42	F56H 22	P10F 92	019G 52	089C ● 81	047H 51	P39-3 ● 2-5-63	
M	P40F 12	P70B 71	F40C 83	F58D 53	067G ● 61	P111B 63	F1H 42	P61I 23	P13E 52	02166 ● 2-3-64	
N	[illegible] 41	[illegible] Control	055E [illegible]	P41I 23	P103C 11	F91A 93	055A 63	F72H 91	069F 22	F2952 2-9-65	
O	[illegible] 72	P25H 51	[illegible] 82	062A 83	094C 41	079F 92	CO-1 2-9-65	078G 43	-- --	P77-5 ● 2-15-66	

10A indicates reuse of holes in Row 10.

● indicates failed specimen.

FIGURE 2
SUMMARY OF QUALITY INDEX RATINGS
Treated Specimens - Retention 1

Preservative	Avg. Ret. lb/ft^3	Exp. Time Mos.	Species
1 Coal Tar Creosote	4.60	180	Oak
	5.30		Fir
	4.30		Pine
2 Chromated Zinc Chloride	0.51	180	Oak
	0.51		Fir
	0.50		Pine
3 Fluor Chrome Arsenate Phenol Type A	0.30	180	Oak
	0.27		Fir
	0.25		Pine
4 Pentachlorophenol	4.30	180	Oak
	4.30		Fir
	4.60		Pine
5 Copper Napthenate	4.30	180	Oak
	4.20		Fir
	4.40		Pine
6 Acid Copper Chromate	0.62	180	Oak
	0.55		Fir
	0.51		Pine
7 Ammoniacal Copper Arsenite	0.29	180	Oak
	0.25		Fir
	0.20		Pine
8 Chromated Zinc Arsenate	0.54	180	Oak
	0.50		Fir
	0.50		Pine
9 Chromated Copper Arsenate	0.43	180	Oak
	0.44		Fir
	0.38		Pine
10 60% Creosote 40% Coal Tar	4.19	156	Oak
	3.98		Fir
	4.13		Pine
11 80% Creosote 20% Coal Tar	3.89	156	Oak
	4.31		Fir
	3.87		Pine
12 50% Creosote 50% Petroleum	4.98	156	Oak
	4.38		Fir
	3.68		Pine
13 25% Creosote 75% Petroleum	4.73	156	Oak
	4.13		Fir
	3.66		Pine

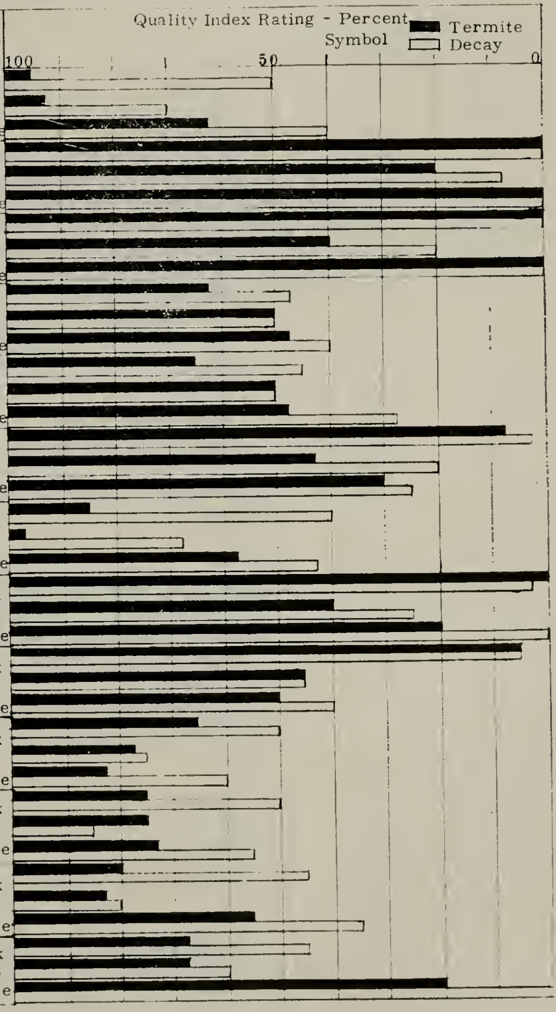


FIGURE 3
SUMMARY OF QUALITY INDEX RATINGS
Treated Specimens - Retention 2

Preservative	Avg. Ret. lb/ft^3	Exp. Time Mos.	Species
1 Coal Tar Creosote	8.70	180	Oak
	8.10		Fir
	7.60		Pine
2 Chromated Zinc Chloride	0.99	180	Oak
	0.94		Fir
	1.00		Pine
3 Fluor Chrome Arsenate Phenol Type A	0.53	180	Oak
	0.53		Fir
	0.50		Pine
4 Pentachlorophenol	8.00	180	Oak
	8.50		Fir
	7.80		Pine
5 Copper Napthenate	8.00	180	Oak
	9.20		Fir
	8.50		Pine
6 Acid Copper Chromate	1.00	180	Oak
	1.17		Fir
	1.00		Pine
7 Ammoniacal Copper Arsenite	0.51	180	Oak
	0.49		Fir
	0.39		Pine
8 Chromated Zinc Arsenate	1.00	180	Oak
	0.99		Fir
	1.02		Pine
9 Chromated Copper Arsenate	0.75	180	Oak
	0.86		Fir
	0.74		Pine
10 60% Creosote 40% Coal Tar	7.83	156	Oak
	8.21		Fir
	8.07		Pine
11 80% Creosote 20% Coal Tar	7.92	156	Oak
	8.24		Fir
	8.02		Pine
12 50% Creosote 50% Petroleum	8.25	156	Oak
	8.36		Fir
	7.88		Pine
13 25% Creosote 75% Petroleum	7.82	156	Oak
	8.17		Fir
	8.32		Pine

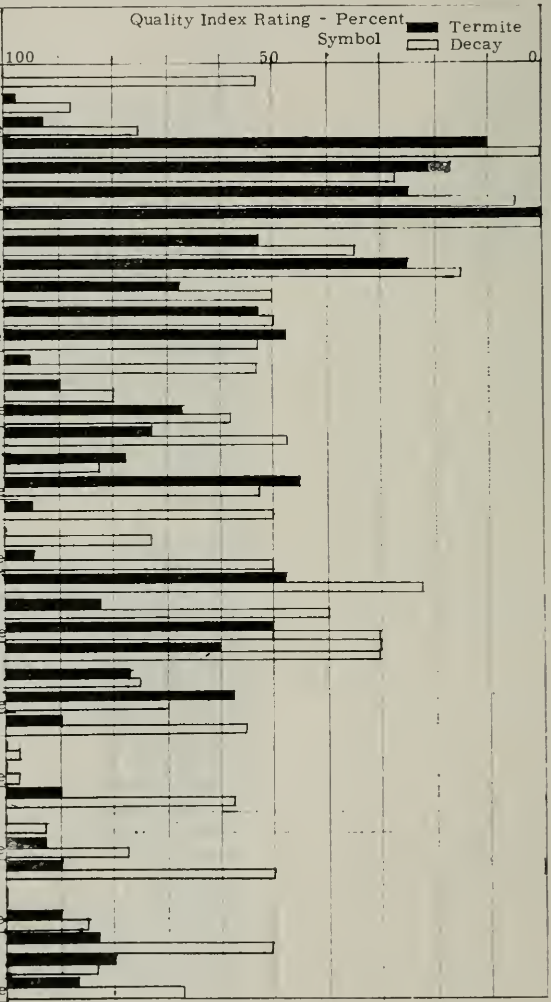
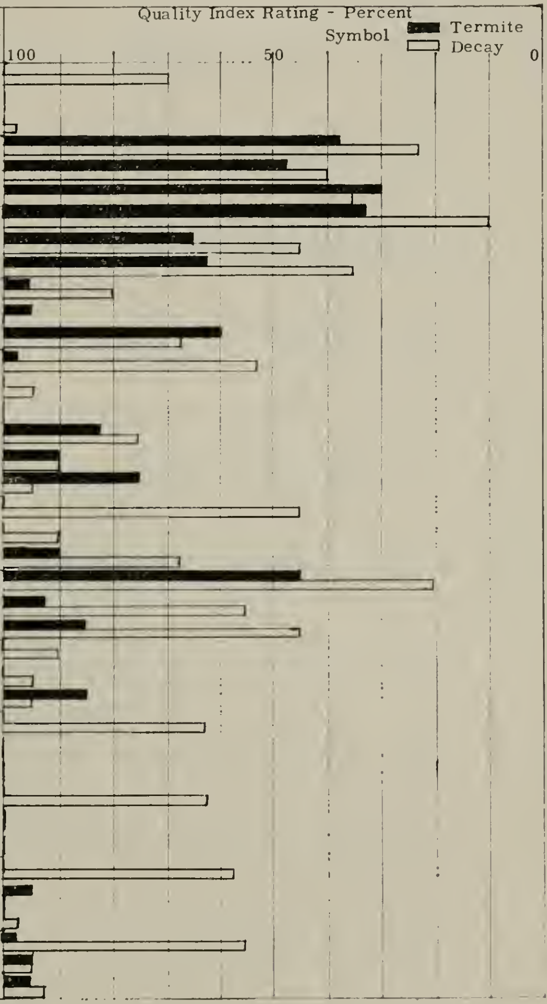


FIGURE 4
SUMMARY OF QUALITY INDEX RATINGS
Treated Specimens - Retention 3

Preservative	Avg. Ret. lb/ft^3	Exp. Time Mos.	Species
1 Coal Tar Creosote	16.4	180	Oak
	16.4		Fir
	15.9		Pine
2 Chromated Zinc Chloride	1.99	180	Oak
	2.00		Fir
	2.04		Pine
3 Fluor Chrome Arsenate Phenol Type A	0.98	180	Oak
	1.08		Fir
	0.99		Pine
4 Pentachlorophenol	15.1	180	Oak
	14.5		Fir
	15.8		Pine
5 Copper Napthenate	12.2	180	Oak
	16.8		Fir
	16.8		Pine
6 Acid Copper Chromate	1.98	180	Oak
	2.13		Fir
	2.07		Pine
7 Ammoniacal Copper Arsenite	1.00	180	Oak
	0.75		Fir
	0.79		Pine
8 Chromated Zinc Arsenate	1.96	180	Oak
	1.86		Fir
	2.00		Pine
9 Chromated Copper Arsenate	1.51	180	Oak
	1.48		Fir
	1.50		Pine
10 60% Creosote 40% Coal Tar	15.92	156	Oak
	16.16		Fir
	16.30		Pine
11 80% Creosote 20% Coal Tar	16.13	156	Oak
	15.92		Fir
	16.27		Pine
12 50% Creosote 50% Petroleum	15.69	156	Oak
	16.27		Fir
	16.41		Pine
13 25% Creosote 75% Petroleum	16.37	156	Oak
	16.27		Fir
	16.56		Pine



EXPLANATION OF SYMBOLS FOR FIGURES 5 TO 13

Number	Symbol	Description of Preservative
1	●	COAL TAR CREOSOTE
2	○	CHROMATED ZINC CHLORIDE
3	■	FLUOR CHROME ARSENATE PHENOL TYPE A
4	□	PENTACHLOROPHENOL
5	▲	COPPER NAPTHENATE
6	△	ACID COPPER CHROMATE (Celcure)
7	◆	AMMONIACAL COPPER ARSENITE (Chemonite)
8	◇	CHROMATED ZINC ARSENATE (Boliden Salt)
9	×	CHROMATED COPPER ARSENATE (Green Salt)
10	⊗	60% CREOSOTE 40% COAL TAR
11	•	80% CREOSOTE 20% COAL TAR
12	◯	50% CREOSOTE 50% PETROLEUM
13	⊕	25% CREOSOTE 75% PETROLEUM

FIG. 5
AVERAGE QUALITY INDEX RATING
RETENTION NO. 1

OAK SPECIES

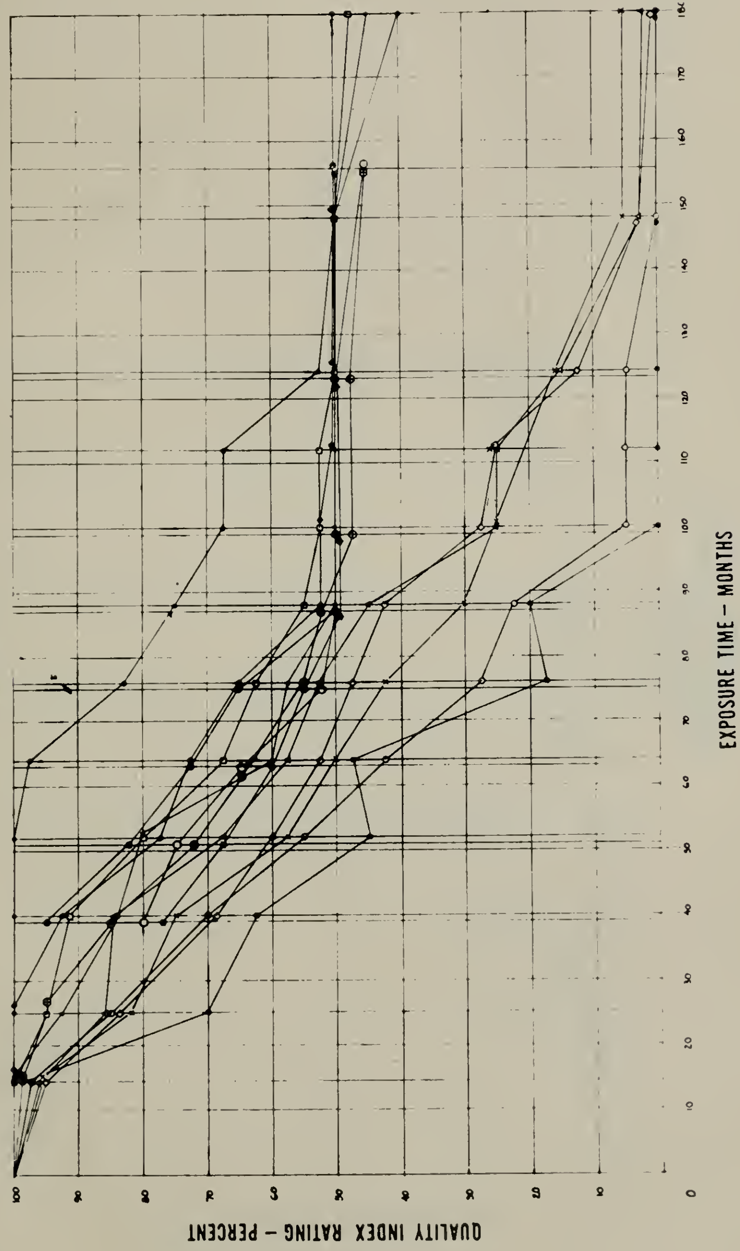


FIG. 6
AVERAGE QUALITY INDEX RATING
RETENTION NO. 1
FIR SPECIES

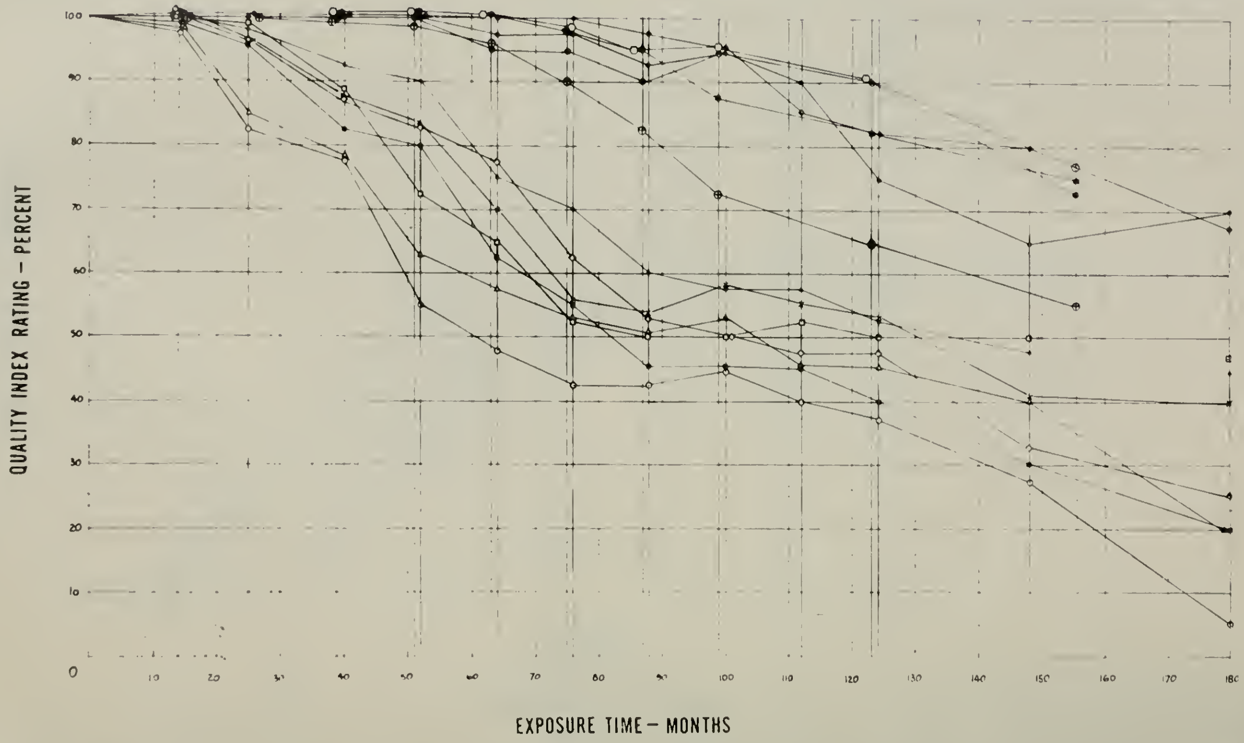


FIG. 7
AVERAGE QUALITY INDEX RATING
RETENTION NO. 1
PINE SPECIES

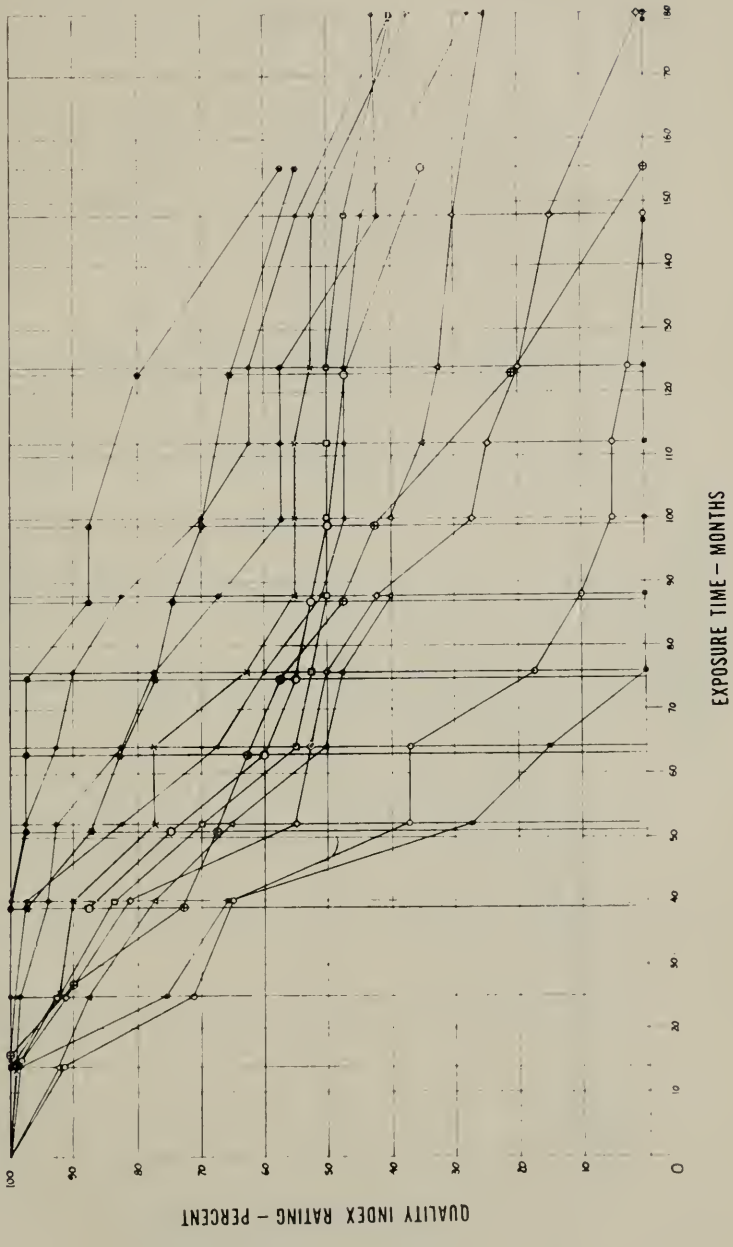


FIG. 8
AVERAGE QUALITY INDEX RATING
RETENTION NO. 2

OAK SPECIES

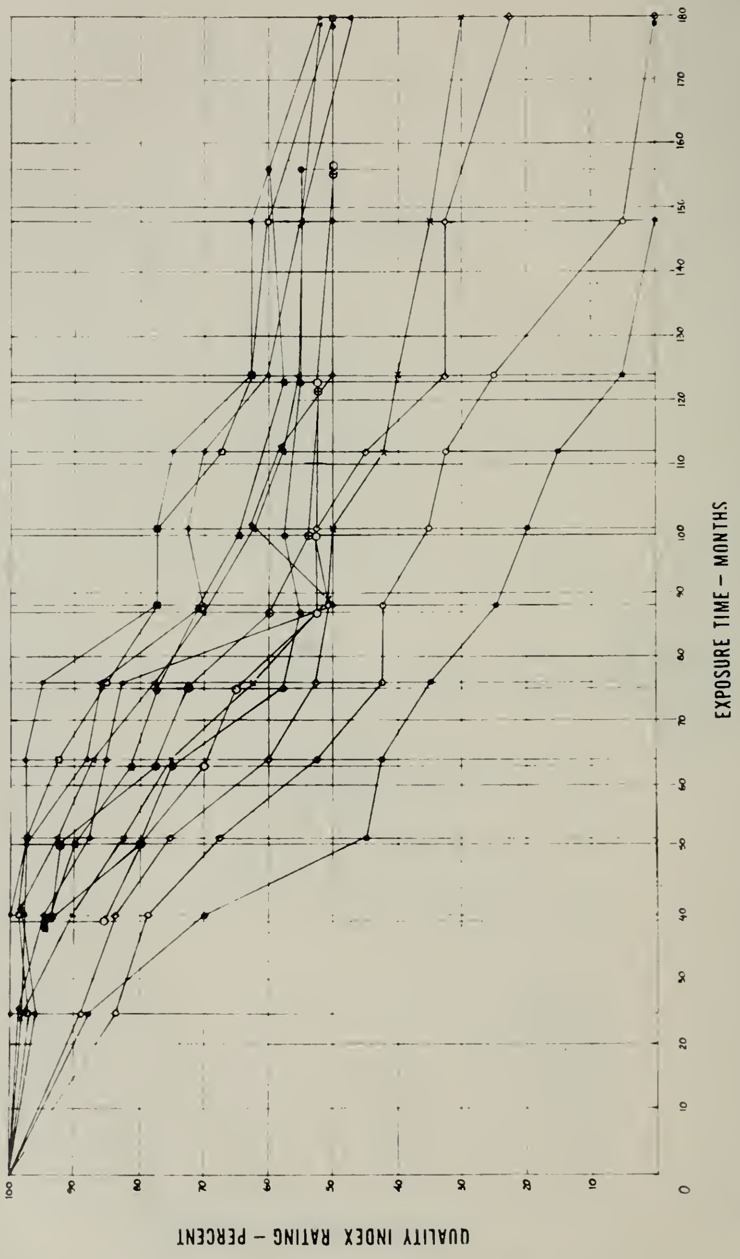


FIG. 9
AVERAGE QUALITY INDEX RATING
RETENTION NO. 2

FIR SPECIES

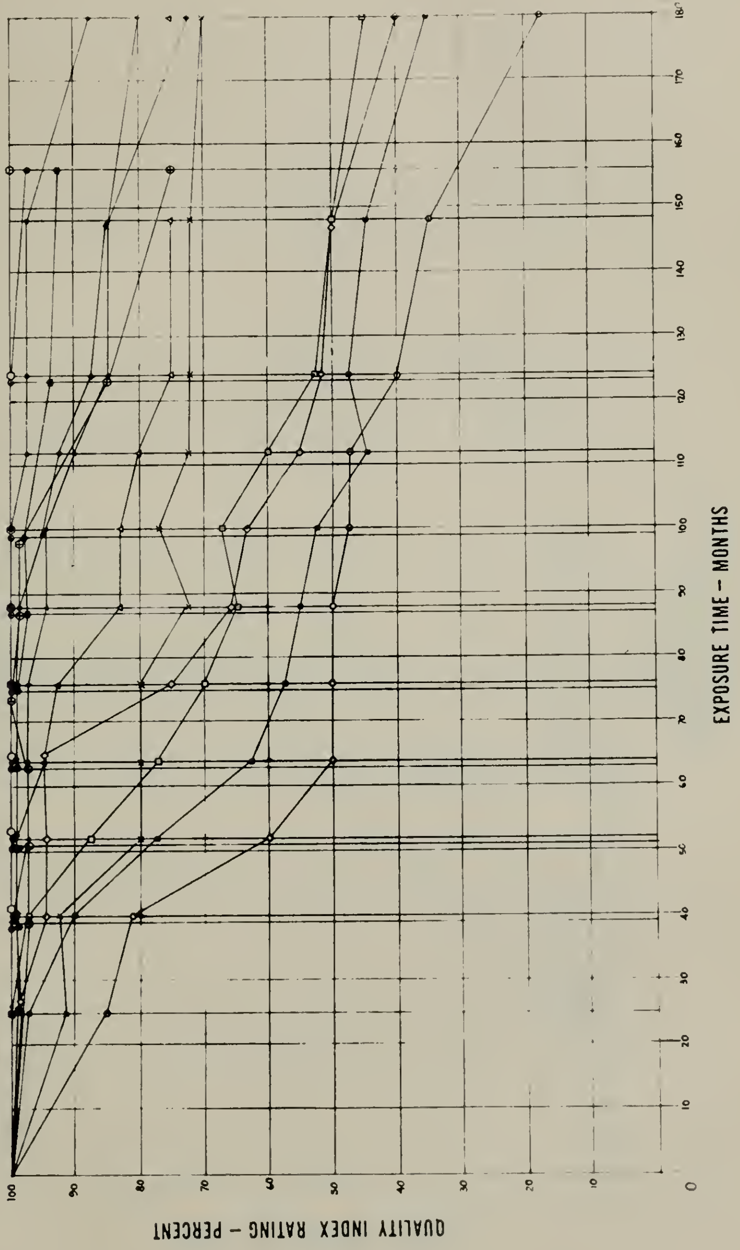


FIG. 10
AVERAGE QUALITY INDEX RATING
RETENTION NO. 2
PINE SPECIES

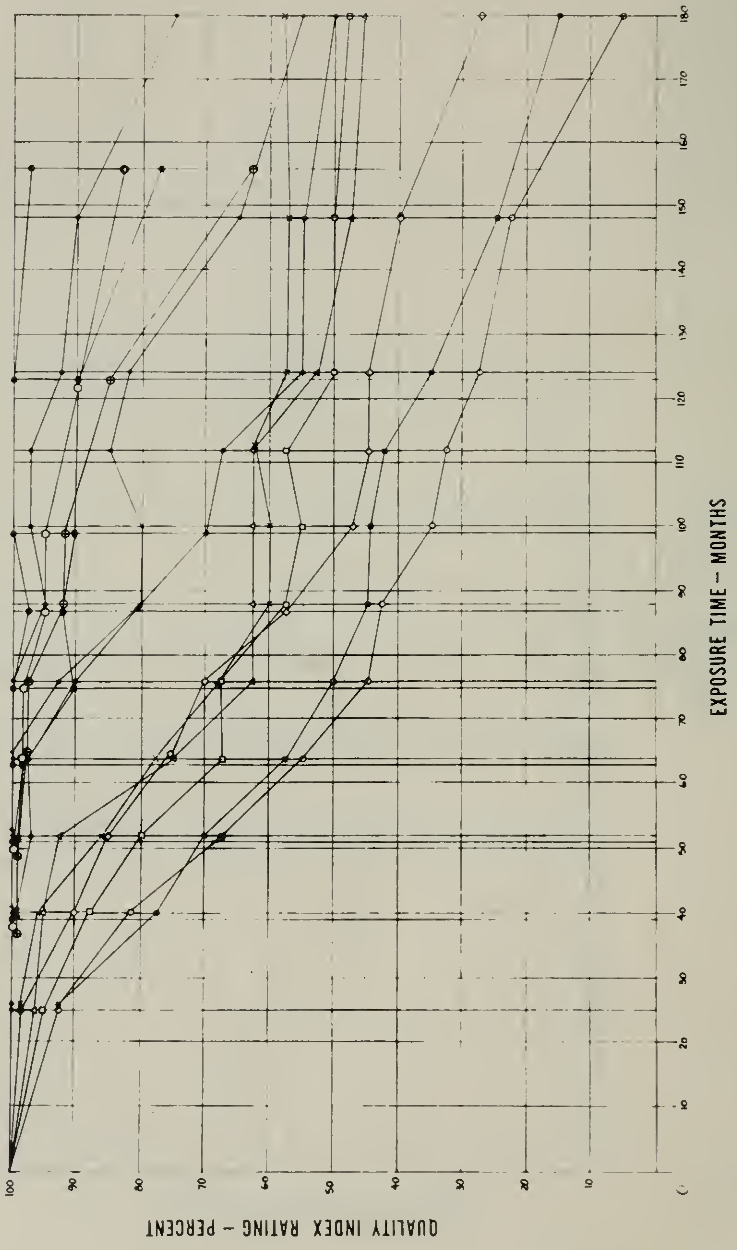


FIG. 11
AVERAGE QUALITY INDEX RATING
RETENTION NO. 3
OAK SPECIES

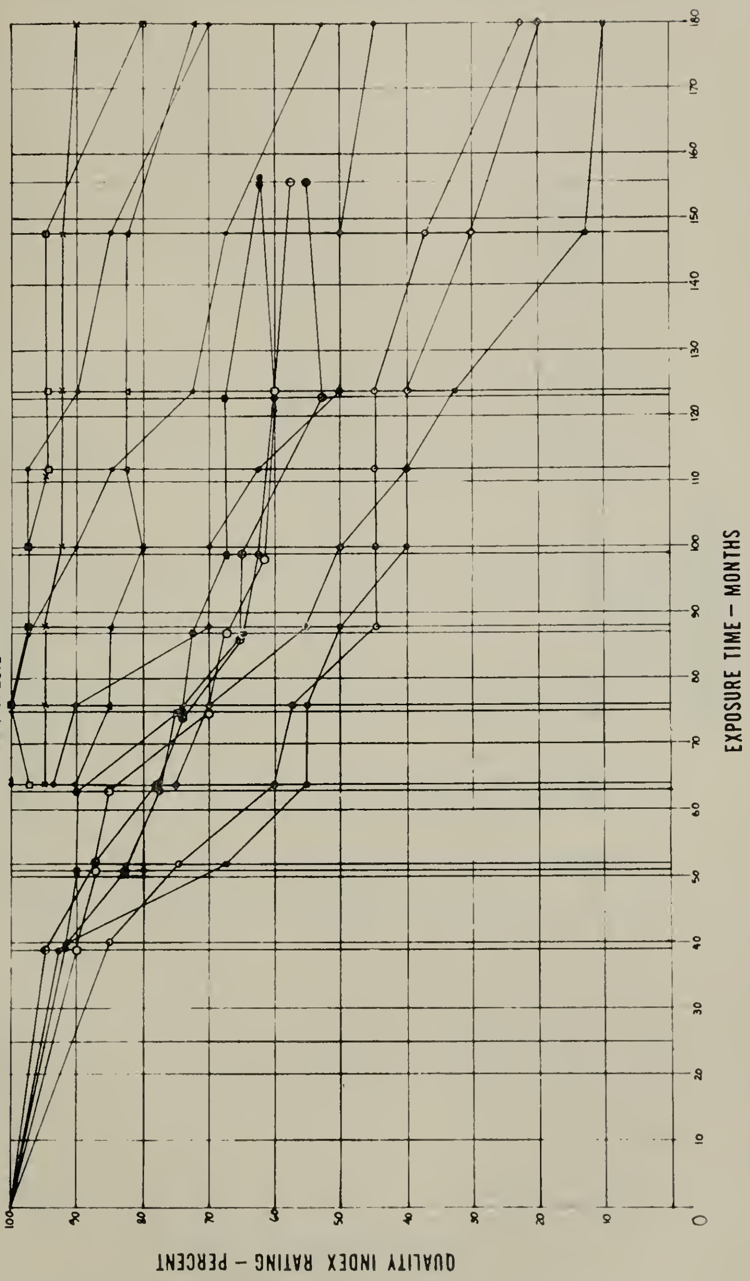


FIG. 12
AVERAGE QUALITY INDEX RATING
RETENTION NO. 3
FIR SPECIES

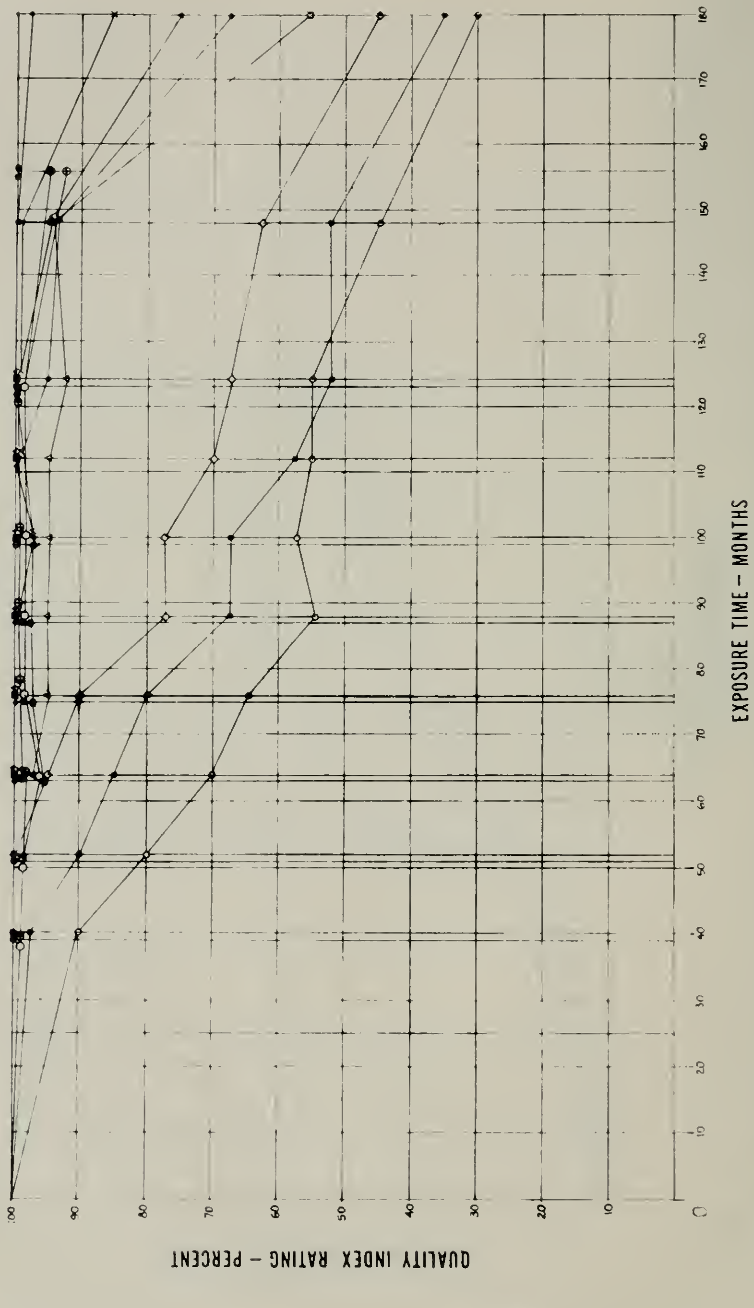


FIG. 13
AVERAGE QUALITY INDEX RATING
RETENTION NO. 3

PINE SPECIES

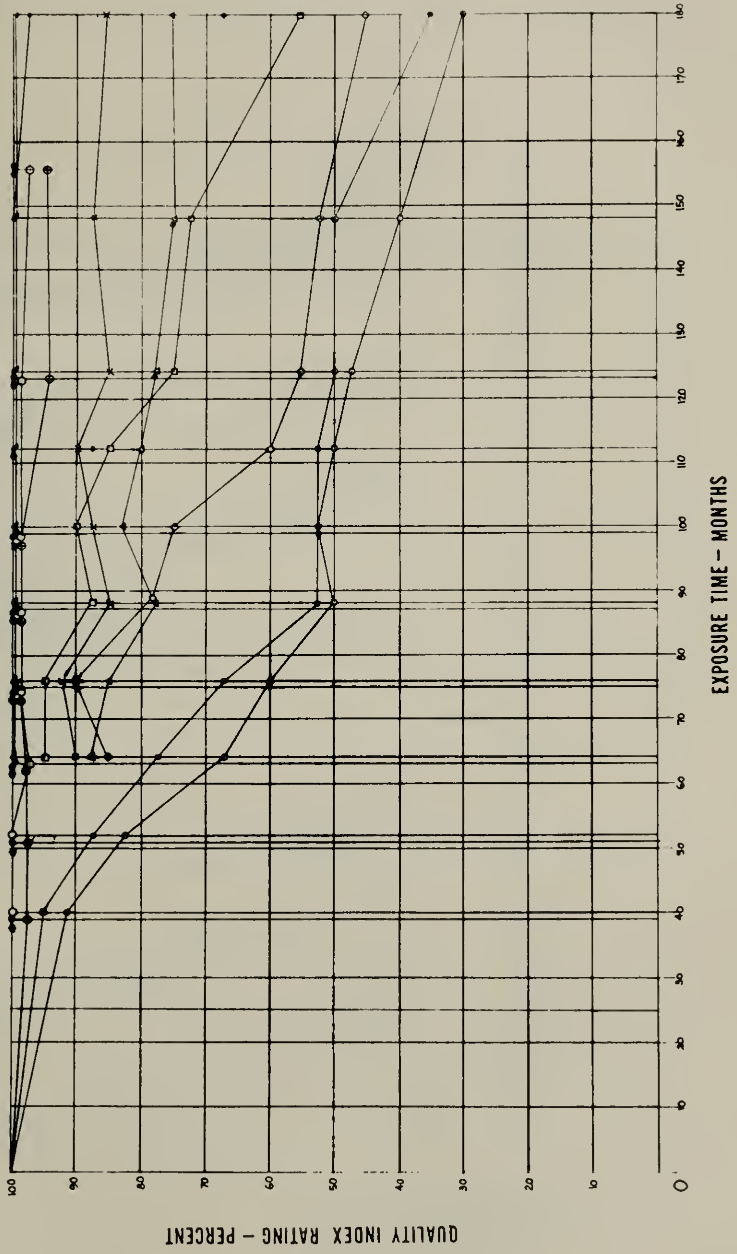
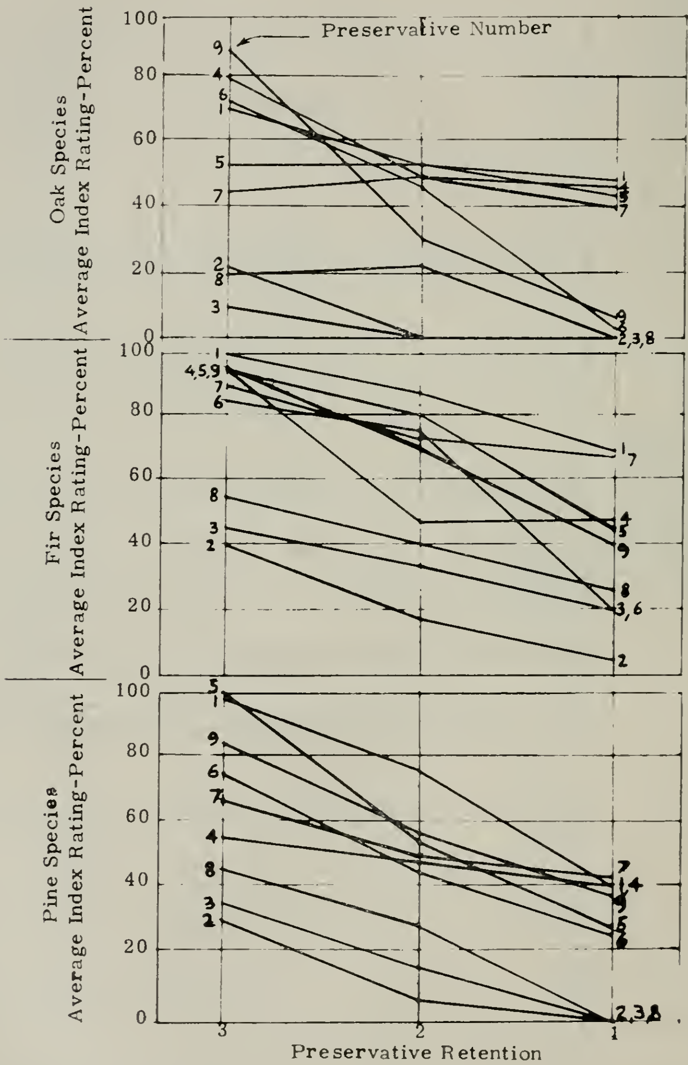


FIGURE 14
EFFECT OF AMOUNT OF PRESERVATIVE ON INDEX RATING



Note: Preservative Retention
1 = 1/2 AREA-Recommended
2 = AREA-Recommended
3 = 2 × AREA-Recommended

TABLE 1
TERMITE CONTROL INVESTIGATION

AAR RESEARCH CENTER
FIELD INSPECTION DATA SHEET

Plot 2

Location		Code	Rating of Condition of Specimens on Indicated Date								
ROW	Position	Number	2-5-62	2-4-63	2-3-64	2-8-65	2-15-66	1-30-67	2-8-68	2-9-70	11-14-72
	1	P94F/32	1B	3C	3C	3C	5C	*	*	*	*
M	2	P40G/92	1A	1A	1B	1C	2C	1C	1C	1C	1C
	3	F103A/32	1A	1A	1A	1C	3C	3C	3C	3C	3C
	4	O12D/21	3B	4C	5C	*	*	*	*	*	*
	5	O107E/81	2B	3B	3B	3C	5C	*	*	*	*
	6	F24H/23	1B	1B	1B	1C	2C	2C	2C	3C	3C
	7	F56C/93	-	1A	1A	1A	1A	1A	1A	1A	1A
	8	P70I/63	-	1A	1A	3B	3A	3C	3C	3C	*
	9	P58I/72	1A	1A	1A	2A	3A	3A	3A	3A	3A
N	1	O103E/42	1A	1A	1A	1A	1A	1A	1A	2B	3B
	2	O61B/83	-	2A	2A	3B	3A	5A	*	*	*
	3	O53G/53	-	1A	1A	1A	1A	1A	1A	2A	3A
	4	O63E/33	2B	3B	3C	3C	4C	4B	5B	*	*
	5	F104E/31	2B	1C	3C	3C	3C	3C	3C	3C	5C
	6	P48B/12	1A	1A	Removed to AAR Lab 2-5-63						
	7	O7I/63	-	1A	1B	2B	2B	2B	2B	2B	2B
	8	P42F/81	2C	3C	3C	3C	3D	5E	*	*	*
	9	O73B/31	3C	3C	3C	3C	5C	*	*	*	*
O	1	F76D/31	1B	1C	2C	3C	3C	3B	3C	4C	5C
	2	P101C/11	1A	1A	1A	1A	1B	1A	2B	2B	3C
	3	F76C/32	1A	2B	3C	3C	3C	3C	3C	3C	3C
	4	F10A/43	-	1A	1A	1A	1A	1A	1A	1A	1A
	5	F51C/83	-	1A	1A	1A	1A	2A	2A	2A	2A
	6	O13G/32	1B	3B	3B	3C	3D	4D	5D	*	*
	7	O15G/91	1B	2B	3B	3C	1A	3C	5C	*	*
	8	O66A/13	-	1A	1A	1A	1A	1A	1A	1A	2A
	9	P42G/41	1B	1C	2C	3C	3C	3C	3C	3C	3C
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										

AWPA Rating Code: Numbers 1 to 5 indicate degree of decay with No. 1 being sound - no evidence of decay.
Letters A to E indicate degree of termite attack with A having no attack.
*Failed and Removed.

TABLE 2
TERMITE CONTROL INVESTIGATION

AAR RESEARCH CENTER
CLASSIFIED DATA SHEETS

Preservative No. 2 - Chromated Zinc Chloride
Retention No. 1

Species	Code Number	Plot Location	Retention lb./cu ft.	Rating of Condition of Specimens on Indicated Date						
				2-3-64	2-8-65	2-15-66	1-31-67	2-8-68	2-9-70	11-14-72
Oak	O 7H	3J9	0.52	5C	*	*	*	*	*	*
	12D	2M4	0.48	5C	*	*	*	*	*	*
	15D	1A5	0.51	3C	3C	5D	*	*	*	*
	20D	8N9	0.48	3C	3C	5E	*	*	*	*
	21C	6J1	0.50	3C	5D	*	*	*	*	*
	23G	4C7	0.52	4C	4C	5C	*	*	*	*
	40G	1F5	0.53	3C	3C	3C	3C	3C	5C	*
	41D	5L5	0.52	5C	*	*	*	*	*	*
	67F	7C8	0.51	3C	4C	5C	*	*	*	*
	84B	9F6	0.48	4D	4D	5D	*	*	*	*
	Months of Service			76	88	100	112	124	148	180
	Av. Termite Rating			45.0	30.0	20.0	5.0	5.0	5.0	0
	Av. Decay Rating			30.0	22.5	5.0	5.0	5.0	0	0
	Av. Index Rating			27.5	22.5	5.0	5.0	5.0	0	0
	No of Failures			3	4	9	9	9	10	10
Fir	F 31F	5I1	0.42	1C	2C	3C	3C	3C	3C	4C
	33G	1K6	0.55	2C	3C	3C	4C	5D	*	*
	44G	9G1	0.59	5D	*	*	*	*	*	*
	45G	9H6	0.48	3D	3D	3C	3D	4C	4C	4C
	53G	7B1	0.44	2C	2C	3C	3C	3C	3C	5C
	55E	10J7	0.49	1C	2C	3C	3C	3C	5C	*
	56G	4C5	0.55	3C	3C	3C	3C	3C	5D	*
	61E	8O5	0.55	2C	3C	3C	3C	3C	3C	5C
	70C	4O7	0.54	3C	3C	3C	3C	3C	3C	4E
	74G	10L5	0.52	3C	3C	3C	3C	3C	3C	5E
	Months of Service			76	88	100	112	124	148	180
	Av. Termite Rating			45.0	42.5	45.0	42.5	42.5	37.5	20.0
	Av. Decay Rating			62.5	52.5	45.0	42.5	37.5	27.5	7.5
	Av. Index Rating			42.5	42.5	45.0	40.0	37.5	27.5	5.0
	No. of Failures			1	1	1	1	2	4	8
Pine	P 27I	2D3	0.50	3C	3C	5C	*	*	*	*
	28H	8L7	0.51	3D	3E	*	*	*	*	*
	31I	9I1	0.50	*	*	*	*	*	*	*
	33H	10F2	0.51	4E	*	*	*	*	*	*
	34I	4I7	0.51	5D	*	*	*	*	*	*
	37I	5C9	0.49	2D	5D	*	*	*	*	*
	38I	7D1	0.50	3D	3D	4E	*	*	*	*
	39J	3F8	0.51	4D	4E	*	*	*	*	*
	47H	10D3	0.50	3D	3D	3C	3C	4E	*	*
	48H	3J8	0.49	4E	*	*	*	*	*	*
	Months of Service			76	88	100	112	124	148	180
	Av. Termite Rating			20.0	12.5	10.0	5.0	0	0	0
	Av. Decay Rating			35.0	22.5	7.5	5.0	2.5	0	0
	Av. Index Rating			17.5	10.0	5.0	5.0	2.5	0	0
	No. of Failures			4	7	9	9	10	10	10

AWPA Rating Code: Nos. 1 to 5 indicate degree of decay with No. 1 being sound - no evidence of decay. Letters A to E indicate degree of termite attack with A having no attack. *Failed and Removed.

TABLE 3
QUALITY INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1964

T-Termite or D=Decay	12 Months Exposure			24 Months Exposure			36 Months Exposure			48 Months Exposure			72 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
T	75.0	55.0	50.0	75.0	35.0	30.0	55.0	10.0	15.0	10.0	10.0	0	0	0	0
D	60.0	65.0	70.0	40.0	35.0	25.0	10.0	20.0	5.0	10.0	0	0	0	0	0
AVG. INDEX	50.0	55.0	50.0	35.0	25.0	20.0	10.0	5.0	0	10.0	0	0	0	0	0
No. of Failures	0	0	0	1	1	2	4	4	5	4	5	5	5	5	5

TABLE 4
QUALITY INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1965

T=Termite or D=Decay	12 Months Exposure			24 Months Exposure			36 Months Exposure			60 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
T	50.0	50.0	50.0	62.5	35.0	30.0	50.0	10.0	5.0	0	0	0
D	75.0	55.0	50.0	50.0	35.0	25.0	50.0	10.0	5.0	0	0	0
AVG. INDEX	50.0	40.0	50.0	50.0	10.0	20.0	50.0	10.0	0	0	0	0
No. of Failures	0	0	0	0	4	3	0	4	5	2	5	5

*only two specimens were installed

TABLE 5
QUALITY INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1966

T=Termite or D=Decay	12 Months Exposure			24 Months Exposure			48 Months Exposure			81 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
T	66.6	45.0	60.0	41.7	35.0	45.0	0	15.0	0	0	15.0	0
D	58.3	60.0	60.0	16.7	40.0	25.0	0	20.0	0	0	0	0
AVG. INDEX	58.3	45.0	50.0	16.7	35.0	25.0	0	15.0	0	0	0	0
No. of Failures	0	0	0	1	1	2	3*	3	5	3*	5	5

*only three specimens were installed

TABLE 6
QUALITY INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1967

T-Termite or D-Decay	12 Months Exposure			36 Months Exposure			60 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
T	75.0	65.0	50.0	35.0	30.0	20.0	20.0	5.0	0
D	80.0	45.0	50.0	35.0	15.0	5.0	0	0	0
AVG. INDEX	75.0	35.0	50.0	30.0	5.0	0	0	0	0
No. of Failures	0	0	0	1	4	0	5	5	5

TABLE 7
SUMMARY OF QUALITY INDEX RATINGS
TREATED SPECIMENS

Preservative	Months of Expos.	T=Termite or D=Decay	No. 1 Retention			No. 2 Retention			No. 3 Retention		
			Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
1	180	T	95.0	92.5	62.5	100.0	97.5	92.5	100.0	100.0	100.0
		D	50.0	70.0	40.0	52.5	87.5	75.0	70.0	100.0	97.5
		AV.	50.0	70.0	40.0	52.5	87.5	75.0	70.0	100.0	97.5
2	180	T	0	20.0	0	10.0	17.5	25.0	37.5	47.5	30.0
		D	0	7.5	0	0	27.5	5.0	22.5	40.0	35.0
		AV.	0	5.0	0	0	17.5	5.0	22.5	40.0	30.0
3	180	T	0	40.0	0	0	52.5	25.0	32.5	65.0	62.5
		D	0	20.0	0	0	35.0	15.0	10.0	45.0	35.0
		AV.	0	20.0	0	0	35.0	15.0	10.0	45.0	35.0
4	180	T	62.5	50.0	47.5	67.5	52.5	47.5	95.0	95.0	60.0
		D	47.5	50.0	40.0	50.0	50.0	52.5	80.0	100.0	67.5
		AV.	47.5	47.5	40.0	50.0	45.0	47.5	80.0	95.0	55.0
5	180	T	65.0	50.0	47.5	95.0	90.0	67.5	97.5	100.0	100.0
		D	45.0	50.0	27.5	52.5	80.0	57.5	52.5	95.0	100.0
		AV.	45.0	45.0	27.5	52.5	80.0	55.0	52.5	95.0	100.0
6	180	T	7.5	42.5	30.0	72.5	77.5	45.0	82.5	90.0	75.0
		D	2.5	20.0	25.0	47.5	82.5	52.5	75.0	90.0	95.0
		AV.	2.5	20.0	25.0	47.5	75.0	45.0	72.5	85.0	75.0
7	180	T	85.0	97.5	57.5	95.0	100.0	95.0	100.0	100.0	90.0
		D	40.0	67.5	42.5	50.0	72.5	50.0	45.0	90.0	67.5
		AV.	40.0	67.5	42.5	50.0	72.5	50.0	45.0	90.0	67.5
8	180	T	0	40.0	20.0	47.5	82.5	50.0	45.0	92.5	85.0
		D	2.5	25.0	0	22.5	40.0	30.0	20.0	55.0	45.0
		AV.	0	25.0	0	22.5	40.0	27.5	20.0	55.0	45.0
9	180	T	5.0	45.0	50.0	60.0	77.5	57.5	100.0	100.0	85.0
		D	5.0	45.0	40.0	30.0	75.0	70.0	90.0	95.0	95.0
		AV.	5.0	40.0	37.5	30.0	70.0	57.5	90.0	95.0	85.0
10	156	T	65.0	77.5	82.5	90.0	100.0	100.0	100.0	100.0	100.0
		D	50.0	75.0	60.0	55.0	97.5	97.5	62.5	100.0	100.0
		AV.	50.0	72.5	57.5	55.0	97.5	97.5	62.5	100.0	100.0
11	156	T	75.0	75.0	72.5	90.0	100.0	92.5	100.0	100.0	100.0
		D	50.0	85.0	55.0	60.0	92.5	77.5	62.5	100.0	100.0
		AV.	50.0	75.0	55.0	60.0	92.5	77.5	62.5	100.0	100.0
12	156	T	80.0	82.5	55.0	90.0	100.0	90.0	100.0	95.0	100.0
		D	45.0	80.0	35.0	50.0	100.0	85.0	57.5	100.0	97.5
		AV.	45.0	77.5	35.0	50.0	100.0	82.5	57.5	95.0	97.5
13	156	T	67.5	67.5	20.0	82.5	80.0	87.5	97.5	95.0	95.0
		D	45.0	60.0	0	50.0	82.5	67.5	55.0	95.0	92.5
		AV.	45.0	55.0	0	50.0	75.0	62.5	55.0	92.5	87.5

Specimens treated with preservatives 1 to 9 inclusive were installed in November 1957.
Speciments treated with preservatives 10 to 13 inclusive were installed in November 1959.
Inspection Date: November, 1972.

TABLE 8
COMPARISON OF QUALITY INDEX RATINGS BETWEEN COAL TAR CREOSOTE AND COMBINATIONS OF CREOSOTE WITH PETROLEUM OR COAL TAR

Preservative	Months of Service	No. 1 Retention			No. 2 Retention			No. 3 Retention		
		Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
1) Coal Tar Creosote	148	52.5	82.5	62.5	62.5	95.0	90.0	85.0	100.0	100.0
10) 30% Creosote 40% Coal Tar	156	50.0	72.5	57.5	55.0	97.5	97.5	62.5	100.0	100.0
11) 80% Creosote 20% Coal Tar	156	50.0	75.0	55.0	60.0	92.5	77.5	62.5	100.0	100.0
12) 50% Creosote 50% Petroleum	156	45.0	77.5	35.0	50.0	100.0	82.5	57.5	95.0	97.5
13) 25% Creosote 75% Petroleum	156	45.0	55.0	0	50.0	75.0	62.5	55.0	92.5	87.5

NOTE: PRESERVATIVE RETENTION

1 = 1/2 AREA Recommended
2 = AREA Recommended
3 = 2 AREA Recommended

TABLE 9

	PRESERVATIVE	DETERIORATION IN % PER MONTH												
		RET. 1 (1/2 AREA)			1/2-A	RET. 2 (1/1-AREA)			1/1-A	RET. 3 (2-AREA)			2-A	OVER-ALL
		Oak	Fir	Pine	Average	Oak	Fir	Pine	Average	Oak	Fir	Pine	Average	AVERAGE
1	COAL TAR CREOSOTE	.28	.17	.33	.26	.07	.07	.14	.16	.17	.00	.02	.06	.16
2	CHROMATED ZINC CHLORIDE	.68	.53	.68	.63	.56	.46	.53	.52	.43	.33	.39	.38	.51
3	FLUOR CHROME ARSENATE PHENOL TYPE A	1.00	.45	1.32	.92	.68	.36	.47	.50	.50	.31	.36	.38	.61
4	PENTACHLOROPHENOL	.29	.29	.33	.30	.28	.31	.29	.29	.11	.03	.25	.13	.24
5	COPPER NAPTHENATE	.25	.25	.40	.30	.26	.11	.25	.21	.26	.03	.00	.10	.20
6	ACID COPPER CHROMATE	.54	.44	.42	.47	.29	.14	.31	.25	.15	.08	.14	.12	.28
7	AMMONIACAL COPPER ARSENITE	.33	.18	.32	.28	.28	.15	.28	.24	.30	.06	.18	.18	.23
8	CHROMATED ZINC ARSENATE	.53	.42	.53	.49	.43	.33	.40	.39	.44	.25	.31	.33	.40
9	CHROMATED COPPER ARSENATE	.53	.33	.35	.40	.39	.17	.24	.27	.06	.03	.08	.06	.24
10	80% CREOSOTE 40% COAL TAR	.32	.18	.27	.26	.28	.02	.02	.11	.24	.00	.00	.08	.15
11	80% CREOSOTE 20% COAL TAR	.32	.16	.29	.26	.26	.05	.14	.15	.24	.00	.00	.08	.16
12	50% CREOSOTE 50% PETROLEUM	.35	.14	.42	.30	.32	.00	.12	.15	.27	.03	.02	.11	.19
13	25% CREOSOTE 75% PETROLEUM	.35	.29	.64	.43	.32	.16	.24	.24	.29	.05	.08	.14	.27
	AVERAGE	.44	.29	.48	.41	.36	.18	.26	.27	.27	.09	.14	.17	.28

APPENDIX A—CHEMICAL ANAYLSIS OF PRESERVATIVES—DESIRED RETENTIONS OF PRESERVATIVES—TYPICAL RECORDS OF TREATMENT

CHEMICAL ANALYSIS OF PRESERVATIVES

No. 1 Coal tar creosote

Characteristic	AREA Specification	Laboratory Analysis
Water content	Not more than 3.0 percent	0.1 percent
Benzol insoluable	Not more than 0.5 percent	0.14 percent
Specific gravity at 38 deg C	Not less than 1.03 percent	1.087 percent
Distillate limits		
Up to 210 deg C	Not more than 5 percent	2.2 percent
235 deg C	Range between 5 to 25 percent	10.2 percent
270 deg C	Not less than 20 percent	31.3 percent
355 deg C	Range between 60 to 85 percent	72.6 percent
Spec.Gr. of fractions at 38 deg		
From 235 deg to 315 deg C	Not less than 1.025 percent	1.0432 percent
315 deg to 355 deg C	Not less than 1.085	1.1211 percent
Coke residue	Not more than 2 percent	1.54 percent

No. 2 Chromated zinc chloride

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Zinc chloride - $ZnCl_2$	Not less than 77.5 percent	80.88 percent
Sodium dichromate ($Na_2Cr_2O_72H_2O$)	Not less than 17.5 percent	19.12 percent

No. 3 Tanalith

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Sodium flouride - NaF	Not less than 22 percent	23.55 percent
Pentavalent Arsenic ($Na_2HA_5O_4$)	Not less than 22 percent	25.65 percent
Hexavalent Chromium (Na_2CrO_4)	Not less than 34 percent	38.90 percent
Dinitrophenol ($(NO_2)2.\ C_6H_3.\ OH$)	Not less than 10 percent	11.90 percent

No. 4 Pentachlorophenol

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Pentachlorophenol Solution	4.5 to 5.5 percent	4.95 percent

Penta Preservative 202 E is a blend of 5 percent by weight of technical pentachlorophenol in 102 E oil. This oil has the following typical characteristics:

APPENDIX A (CONT'D)

API Gravity at 60°F.	29
Viscosity at 100°F. (SUS)	40
Pour point °F.	0
Flash point, PMCC °F	190
I. B. P.	432
10%	465
50%	516
90%	615
F. B. P.	708
% Penta solvency at 75°F.	13

KEY

API - American Petroleum Institute
SUS - Saybolt Universal Seconds
PMCC - Pensky-Martens Closed Cup Test
I. B. P. - Initial Boiling Point
F. B. P. - Final Boiling Point

No. 5 Copper naphthenate

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Copper	Not less than 0.10 lb per cu ft	0.096 lb per cu ft
	Manufacturers Specification	Typical Analysis
Solvent - Aromatic H-B oil as follows:		
API Gravity 60°F	24 (max)	20.5
Viscosity 100°F (SUS)	----------------	45
Pour point °F	----------------	Minus 10
Distillation Range °F		
I. B. P.	400	490
10%	----------------	512
50%	----------------	540
90%	----------------	584
F. B. P.	700	614
Flash point, PMCC °F	190 (min)	230

No. 6 Acid copper chromate (Celcure)

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Copper Sulphate ($CuSO_4 . 5H_2O$)	Not less than 45 percent	47.3 percent
Sodium Dichromate ($Na_2Cr_2O_7 . 2H_2O$)	Not less than 45 percent	52.7 percent
Chromic Acid (CrO_3)	1.70 percent	None shown as such

No. 7 Ammoniacal copper arsenite (Chemonite)

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis Solution 1	 Solution 2
Copper Hydroxide ($Cu(OH)_2$)	Not less than 55.7 percent	63.6 percent	63.0 percent
Arsenic trioxide (As_2O_3)	Not less than 38.7 percent	36.4 percent	37.0 percent
Acetic acid ($CH_3CO\ OH$)	1.6 percent	None shown as such	

APPENDIX A (CONT'D)

No. 8 Chromated zinc arsenate (Boliden salt)

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Arsenic acid (H_3AsO_4)	Not less than 19 percent	17.6 percent
Sodium arsenate (Na_2HAsO_4)	Not less than 18 percent	22.9 percent
Sodium dichromate ($Na_2Cr_2O_7 . 2H_2O$)	14 percent	16.1 percent
Zinc sulphate ($ZnSO_4 7H_2O$)	Not less than 41 percent	43.4 percent
Subject to the following tolerance: Total arsenic in both arsenic acid and sodium arsenate.	Range 26.4 to 31.1 percent	Based on atomic weights, total arsenic calculated as 28.45 percent

No. 9 Chromated copper arsenate (Green salt)

Treating Solution

Characteristic	AREA Specification	Laboratory Analysis
Potassium dichromate K_2Cr_2O7	Not less than 50 percent	55.3 percent
Copper sulphate CuS $O_4 5H_2O$	Not less than 30 percent	32.3 percent
Arsenic pentoxide $As_2O_5 2H_2O$	Not less than 10 percent	12.4 percent

DESIRED RETENTION OF PRESERVATIVES

	Retention, lb per cu ft		
Preservative	No. 1	No. 2	No. 3
No. 1 Coal tar creosote	4.0	8.0	16.0
No. 2 Chromated zinc chloride	0.5	1.0	2.0
No. 3 Tanalith	0.25	0.50	1.0
No. 4 Pentachlorophenol	4.00	8.00	16.00
No. 5 Copper napthenate	4.00	8.00	16.00
No. 6 Acid copper chromate (Celcure)	0.50	1.00	2.00
No. 7 Ammoniacal copper arsenite (Chemonite)	0.25	0.50	1.00
No. 8 Chromated zinc arsenate (Boliden salt)	0.50	1.00	2.00
No. 9 Chromated copper arsenate (Greensalt)	0.375	0.75	1.50

TYPICAL RECORD OF TREATMENT *

Date: August 16, 1957
Preservative: Coal tar creosote
Retention : 4 lb (desired)
Size of Specimen: 1 5/8 x 3 5/8 x 18
Volume of Specimen: 0.05808 cu ft
90 lb air on at 7:56 a.m.
Fill Cylinder at 8:11 a.m.
175 lb pressure on at 8:15 a.m.
175 lb pressure off at 10:15 a.m.
26 in. final vacuum on at 10:18 a.m.
26 in. final vacumm off at 10:48 a.m.
Temperature: 195 to 200 deg F

*Data furnished by Forest Product Laboratory, Madison, Wis.

Appendix A (Cont'd)

TYPICAL RECORD OF TREATMENT (continued)

Species	Specimen Number	Untreated Weight Lb	Treated Weight Lb	Retention Lb.	Retention Lb/cu ft	Specimens Selected
Oak	O1E/11	2.40	2.78	0.38	6.6	
	O2C	2.80	3.07	0.27	4.6	x
	O4G	2.70	2.97	0.27	4.6	x

No. 10 60% Cresote-40% Coal tar

Treating Solution Characteristic	Laboratory Analysis
Specific gravity at 38°/15.5°C.	1.109
Distillation	
Up to 210°C.	1.0%
235°C.	5.5
270°C.	19.4
315°C.	39.4
355°C.	64.2
Residue	34.4
Volatiles	.4
Moisture - less than 1%	
Benzol insolubles	1.60%
Coke residue	4.96

Specific gravity fraction 235°-315° C. - 1.0480 at 38° C./15.5°C.
Specific gravity fraction 315°-355° C. - 1.1222 at 38°C./15.5°C.

No.11 80% Creosote-20% Coal tar

Treating Solution Characteristic	Laboratory Analysis
Specific gravity at 38°C.	1.100
Distillation	
Up to 210°C.	.7%
235°C.	5.7
270°C.	20.1
315°C.	41.9
355°C.	70.3
Residue	29.2
Volatiles	.5
Moisture - less than 1%	
Benzol insolubles	1.00%
Coke residue	3.36

Specific gravity fraction 235°-315° C.-1.0474 at 38°C./15.5°C.
Specific gravity fraction 315°-355°C. -1.1558 at 38°C./15.5°C.

APPENDIX A (CONT'D)

No. 12 50% Creosote -50% Petroleum

Treating Solution Characteristic	Laboratory Analysis
Specific gravity at 38°/15.5°C.	1.035
Distillation	
Up to 210° C.	.2%
235°C.	2.7
270°C.	16.5
315°C.	40.8
355°C.	59.9
Residue	39.5
Volatiles	.6
Moisture - less than 1%	
Benzol insolubles	.035 percent
Coke residue	4.27 percent

Specific gravity fraction 235°-315°C. - 1.0108 at 38°C./15.5°C.
Specific gravity fraction 315°-355°C. - 1.0636 at 38°C./15.5°C.

No. 13 25% Creosote-75% Petroleum

Treating Solution Characteristic	Laboratory Analysis
Specific gravity at 38°/15.5°C.	1. 1.0145
Distillation	
Up to 210°C.	0%
235°C.	.5
270°C.	9.3
315°C.	31.5
355°C.	48.6
Residue	51.0
Volatiles	.4
Moisture - less than 1%	
Benzol insolubles	.05 percent
Coke residue	6.14 percent

Specific gravity fraction 235°-315°C. -0.9809 at 38°C./15.5°C.
Specific gravity fraction 315°-355°C. -1.0109 at 38°C./15.5°C.

APPENDIX A (CONT'D)

DESIRED RETENTION OF PRESERVATIVES

Preservative	Retention, lb. per cu. ft. No. 1	No. 2	No. 3
No. 10 Creosote-Coal tar (60-40)	4.0	8.0	16.0
No. 11 Creosote-Coal tar (80-20)	4.0	8.0	16.0
No. 12 Creosote-Petroleum (50-50)	4.0	8.0	16.0
No. 13 Creosote-Petroleum (25-75)	4.0	8.0	16.0

TYPICAL RECORD OF TREATMENT *

Date: September 10, 1959
Preservative: 60 percent creosote and 40 percent coal tar
Retention: 4lb (desired)
Size of Specimen: 1 5/8 x 3 5/8 x 18
Volume of Specimen: 0.05808 cu. ft.
90 PSI air on 8:39 a.m.
Fill Cylinder at 8:54 a.m.
175 PSI pressure at 8:55 a.m.
175 PSI pressure off at 11:55 a.m.
27 1/2 in. vacuum on at 11:59 a.m.
27 1/2 in. vacuum off at 12:29 p.m.
Temperature: 200°F.

Species	Specimen Number	Untreated Weight lb.	Treated Weight lb.	Retention Lb.	Retention Lb. /cu. ft.	Specimen Selected
Oak	O1BE-101	2.72	2.98	0.26	3.9	x
Oak	O2AB-101	2.68	2.86	0.18	2.7	
Oak	O9AB-101	2.65	2.94	0.29	4.3	x

*Data furnished by the Forest Product Laboratory, Madison, Wis.

Note: Desired retention of preservative Nos. 1–9 shown on page 37.

APPENDIX B

TREATMENT SCHEDULE OF PRESERVATIVES

#1 Preservative: Coal tar creosote

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	-		-		-	
" air (psi)	90	0:15	90	0:15	95	0:15
Fill cylinder		0:04		0:04		0:05
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:03		0:04		0:05
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	195-200		195-200		195-200	
Retention: 2						
Initial vacuum (inch)	-		-		-	
" air (psi)	15	0:15	50	0:15	70	0:15
Fill cylinder		0:03		0:03		0:05
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:04		0:03		0:05
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated	80	0:05				
Vacuum (inch) " "		3:20				
Temperature F°	195-200		190-195		195-200	
Retention: 3						
Initial vacuum (inch)		0:15	-		-	
" air (psi)		-	3	0:15	30	0:15
Fill cylinder		0:05		0:03		0:05
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:05		0:04		0:05
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	195-200		195-200		195-200	

APPENDIX B (CONT'D)

#2 Preservative: Chromated zinc chloride

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:15
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	unheated		room temp.		room temp.	
Retention: 2						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:15		0:10		0:15
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	unheated		room temp.		room temp.	
Retention: 3						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-			
Fill cylinder		0:15		0:15		0:15
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	unheated		room temp.		room temp.	

APPENDIX B (CONT'D)

#3 Preservative: Flour chrome arsenate phenol type A

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:13
Pressure (psi)	150	2:00	150	2:00	150	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 2						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:13		0:10		0:10
Pressure (psi)	150	2:00	150	2:00	150	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 3						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:10
Pressure (psi)	150	2:00	150	2:00	150	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	

APPENDIX B (CONT'D)

#4 Preservative: Pentachlorophenol

	Length of time in hr: min.					
Species:	Oak		Fir		Pine	
Retention						
Initial vacuum (inch)	-		-		-	
" air (psi)	60	0:15	75	0:15	80	0:15
Fill cylinder		0:02		0:03		0:13
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:05		0:05		0:03
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated	50	0:02	0	0:15	0	0:17
Vacuum (inch) " "	26	1:03	26	0:30	26	0:15
Temperature F°						
Retention: 2						
Initial vacuum (inch)	-		-		-	
air (psi)	30	0:15	50	0:15	40	0:15
Fill cylinder		0:02		0:05		0:02
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:05		0:05		0:03
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated			0	0:20	0	0:15
Vacuum (inch) " "			26	0:15	26	0:15
Temperature F°						
Retention: 3						
Initial vacuum (inch)	5	0:15	-			
" air (psi)	-		10	0:15	20	0:15
Fill cylinder		0:18		0:05		0:05
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:05		0:05		0:02
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated			80	0:02		
Vacuum (inch) " "			26	0:18		
Temperature F°						

APPENDIX B (CONT'D)

#5 Preservative: Copper naphtenate

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	-		-		-	
" air (psi)	20	0:15	70	0:15	85	0:15
Fill cylinder		0:02		0:03		0:03
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:04		0:06		0:02
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated			0	0:20		
Vacuum (inch) " "			26	0:30		
Temperature F°	-		-			
Retention: 2						
Initial vacuum (inch)	15	0:15	-		-	
" air (psi)	-		30	0:15	40	0:15
Fill cylinder		0:04		0:06		0:02
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:03		0:03		0:03
Final vacuum (inch)	26	0:30	26	0:30	26	0:30
Air (psi) - if retreated	0	0:10			0	0:05
Vacuum (inch) " "	26	0:20			26	1:50
Temperature F°	-		-		-	
Retention: 3						
Initial vacuum (inch)	26	0:15	-		-	
" air (psi)	-		-		15	0:15
Fill cylinder		0:05				0:02
Pressure (psi)	175	2:00	150	2:00	150	2:00
Force back		0:04		0:04		0:05
Final vacuum (inch)	26	0:15	26	0:30	26	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	

APPENDIX B (CONT'D)

#6 Preservative: Acid copper chromate

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:10
Pressure (psi)	125	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-				-	
Retention: 2						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:10
Pressure (psi)	125	2:40	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 3						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:12		0:10
Pressure (psi)	125	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-			

APPENDIX B (CONT'D)

#7 Preservative: Ammoniacal copper arsenite

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:07		0:05		0:05
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 2						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:07		0:05		0:06
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°			-			
Retention: 3						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:07		0:08		0:07
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	

Appendix B (Cont'd)

#8 Preservative: Chromated zinc arsenate

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:08		0:06		0:07
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 2						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:08		0:07		0:06
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 3						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:06		0:07
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back		0:32		0:35		
Final vacuum (inch)		0:08	26	0:10		
Air (psi) - if retreated	175	0:10	150	0:30		
Vacuum (inch) " "						
Temperature F°	-		-		-	

APPENDIX B (CONT'D)

#9 Preservative: Chromated copper arsenate

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:06
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back						
Final vacuum (inch)						
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 2						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:10		0:05
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back				0:36		
Final vacuum (inch)			26	?		
Air (psi) - if retreated			125	0:15		
Vacuum (inch) " "						
Temperature F°	-		-		-	
Retention: 3						
Initial vacuum (inch)	26	0:15	26	0:15	26	0:15
" air (psi)	-		-		-	
Fill cylinder		0:10		0:07		0:05
Pressure (psi)	150	2:00	125	2:00	125	2:00
Force back		0:31				
Final vacuum (inch)	26	0:15				
Air (psi) - if retreated	90(175)*	14:40				
Vacuum (inch) " "	0	0:30				
Temperature F°	-		-		-	

* raised from 90 to 175 during last 1/2 hour

APPENDIX B (CONT'D)

#10 Preservative: 60% creosote 40% coal tar

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	-		-		-	
" air (psi)	70	0:15	85	0:15	90	0:15
Fill cylinder		0:01		0:01		0:04
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:04		0:01		0:03
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	200		200		200	
Retention: 2						
Initial vacuum (inch)	-		-		-	
" air (psi)	30	0:15	55	0:15	55	0:15
Fill cylinder		0:02		0:01		0:02
Pressure (psi)	175	3:00	125	3:00	150	2:00
Force back		0:01		0:02		0:01
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	200		200		200	
Retention: 3						
Initial vacuum (inch)	27.5	0:15	-		-	
" air (psi)			25	0:15	25	0:15
Fill cylinder		0:01		0:02		0:02
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:01		0:01		0:11
Final vacuum (inch)	5	0:30	27.5	0:30	27.5	0:20
Air (psi) - if retreated	90	14:00				
Vacuum (inch) " "	27.5	0:15				
Temperature F°	200		200		200	

APPENDIX B (CONT'D)

#11 Preservative: 80% creosote 20% coal tar

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	-		-		-	
" air (psi)	70	0:15	85	0:15	90	0:15
Fill cylinder		0:01		0:01		0:01
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:02		0:01		0:01
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	200		200		200	
Retention: 2						
Initial vacuum (inch)	-		-		-	
" air (psi)	30	0:15	60	0:15	60	0:15
Fill cylinder		0:01		0:02		0:01
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:01		0:03		0:01
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated						
Vacuum (inch) " "						
Temperature F°	200		200		200	
Retention: 3						
Initial vacuum (inch)	3	0:15	-		-	
" air (psi)	-		25	0:20	25	0:15
Fill cylinder		0:01		0:01		0:01
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:04		0:01		0:01
Final vacuum (inch)	27.5	0:15	27.5	0:30	27.5	0:30
Air (psi) - if retreated	90	16:21				
Vacuum (inch) " "	27.5	0:05				
Temperature F°	200				200	

APPENDIX B (CONT'D)

#12 Preservative: 50% creosote 50% petroleum

	Length of time in hr: min.					
Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	-		-		-	
" air (psi)	55	0:15	65	0:15	85	0:35
Fill cylinder		0:02		0:01		0:01
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:01		0:02		0:02
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated	100	?	100	0:15		
Vacuum (inch) " "	27	0:15	27.5	1:00		
Temperature F°	200		200		200	
Retention: 2						
Initial vacuum (inch)	-		-		-	
" air (psi)	22	0:15	20	0:15	45	0:15
Fill cylinder		0:02		0:01		0:02
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:02		0:01		0:02
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated				0:15		
Vacuum (inch) " "			27.5	0:35		
Temperature F°	200		200		200	
Retention: 3						
Initial vacuum (inch)	-		27.5	0.15	-	
" air (psi)	-		-		15	0:15
Fill cylinder				0:02		0:01
Pressure (psi)	175	3:00	125	3:30	150	2:00
Force back		0:01				0:01
Final vacuum (inch)	27.5	0:30			27.5	0:30
Air (psi) - if retreated	175		100	0:15		
Vacuum (inch) " "	27.5	0:15	27.5	14:00		
Temperature F°	200		200		200	

APPENDIX B (CONT'D)

#13 Preservative: 25% creosote 75% petroleum

Length of time in hr: min.

Species:	Oak		Fir		Pine	
Retention: 1						
Initial vacuum (inch)	-		-		-	
" air (psi)	35	0:15	50	0:15	90	0:15
Fill cylinder		0:02		0:15		0:01
Pressure (psi)	175	3:00	125	4:00	150	2:00
Force back		0:01		0:03		0:03
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated	75	0:15	75	0:15		
Vacuum (inch) " "	27.5	0:45	27.5	1:00		
Temperature F°	200		200		200	
Retention: 2						
Initial vacuum (inch)	-		-		-	
" air (psi)	15	0:15	15	0:15	40	0:15
Fill cylinder		0:02		0:02		0:01
Pressure (psi)	175	3:00	125	2:00	150	2:00
Force back		0:01		0:03		0:03
Final vacuum (inch)	27.5	0:30	27.5	0:30	27.5	0:30
Air (psi) - if retreated			90	15:00	90	0:15
Vacuum (inch) " "			27.5	0:05	27.5	1:00
Temperature F°	200		200		200	
Retention: 3						
Initial vacuum (inch)	-		5*		-	
" air (psi)	15	0:15	125	2:00	5	0:15
Fill cylinder		0:02				0:02
Pressure (psi)	175	3:00	125	3:35	150	2:00
Force back		0:01				0:01
Final vacuum (inch)	27.5	0:30	27.5*		27.5	0:30
Air (psi) - if retreated	90	14:15	90	14:30	100	0:15
Vacuum (inch) " "	27.5	0:15			27.5	1:00
Temperature F°	200		200		200	

* to fill cylinder

Advance Report of Committee 3—Ties and Wood Preservation
Report on Assignment 5

Service Records

K. C. Edscorn *(chairman, subcommittee)*, L. C. Collister, M. J. Crespo, E. M. Cummings, J. K. Gloster, H. E. Richardson, R. H. Savage.

TIE RENEWALS AND COSTS

Statistics providing information on cross tie renewals and average tie costs for the year 1973, as compiled by the Economics and Finance Department, Association of American Railroads, are presented on following pages in Tables A and B.

The 1973 statistics on new tie renewals by Class I U. S. Railroads compared with 1972 are as follows:

Year	*Total New Tie Renewals*	*Renewals Per Mile*
1972	20,571,423*	70
1973	17,856,780**	61

---

* Includes 31,021 concrete ties, excludes 394,089 secondhand ties.
** Includes 28,635 concrete ties, excludes 819,324 secondhand ties.

By geographical districts, the Eastern Roads inserted in replacement 56 ties per mile, the Southern Roads 100 ties per mile and the Western Roads 52 ties per mile.

"Indicated" wooden tie life determined by dividing the total number of ties in track (1967 figures) by the number of new ties inserted in 1973 is as follows: Eastern Roads 54 years, Southern Roads 31 years, Western Roads 58 years, all U. S. Class I Roads 49 years.

The reports show some significant contrasts to 1972. While total replacements decreased by 13%, the average cost of these ties increased about 10%. This is obviously the result of rising demand in the face of less supply due to a very competitive lumber market. Weather conditions for a nine-month period during the year also curtailed production of the soft hardwood species, some of which would have been available for treatment during the winter months. Of the total decrease, 70% was on the Western District; 30% was on the Southern District, while the Eastern District replacements equalled the 1972 figure.

Competitive conditions in the hardwood lumber market also contributed to an increase of $0.56 in the average cost of wooden ties.

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1973

District and Road	Wooden cross ties laid in replacement			Track maintained by reporting railroad			Equated gross ton-miles (thousands) a		New cross tie replacement averages			
	New ties		Second hand ties	Miles occupied by cross ties c	Total cross ties	Cross ties per mile (1967)	Total	Per mile of track	Percent renewal to all ties	Number laid per mile	Renewal cost per mile	Renewal cost per 1,000 GTM
	Number	Average cost b										
	1	2	3	4	5	6	7	8	9	10	11	12
EASTERN DISTRICT:												
Akron, Canton & Youngstown	5 745	$6.85	246	217	641 199	2 950	712 093	3 282	0.90	26	$180	5.48¢
Ann Arbor	14 650	6.42	-	403	1 224 953	3 042	1 257 822	3 121	1.20	36	233	7.47
Baltimore & Ohio	402 127	5.97	-	9 213	26 717 520	2 900	73 050 724	7 929	1.51	44	260	3.28
Bangor & Aroostook	39 070	7.68	-	759	2 182 223	2 874	1 418 212	1 869	1.79	51	395	21.15
Bessemer & Lake Erie	40 262	9.13	1 060	396	1 188 720	3 000	3 972 470	10 031	3.39	102	927	9.24
Boston & Maine	155 404	7.03	-	1 969	5 807 164	2 950	7 538 257	3 828	2.68	79	555	14.50
Canadian Pacific (Lines in Me.)	7 861	6.81	-	213	626 038	2 935	1 559 208	7 320	1.26	37	254	3.46
Central RR of New Jersey	11 379	6.72	-	706	1 974 757	2 798	2 240 560	3 174	0.58	150	108	3.39
Central Vermont	37 869	6.23	105	444	1 279 198	2 882	1 063 960	2 396	2.96	85	532	22.18
Chesapeake & Ohio	293 025	5.89	-	7 981	23 944 020	3 000	62 902 890	7 882	1.22	37	216	2.75
Chicago & Eastern Illinois	41 216	5.56	-	698	2 123 101	3 043	7 952 888	11 394	1.94	59	328	2.88
Delaware & Hudson	64 690	7.49	3 179	1 024	3 173 986	3 100	6 445 048	6 294	2.04	63	473	7.51
Detroit & Toledo Shore Line	525	7.52	375	137	398 168	2 896	600 813	4 385	0.13	4	29	0.67
Detroit, Toledo & Ironton	31 750	6.68	-	597	1 720 282	2 880	3 647 198	6 109	1.85	53	355	5.81
Elgin, Joliet & Eastern	84 355	6.85	-	802	2 452 823	3 058	2 153 226	2 685	3.44	105	721	26.84
Erie Lackawanna	333 622	7.37	13 991	5 253	15 549 425	2 960	42 154 666	8 025	2.15	64	468	5.83
Grand Trunk Western	109 367	6.99	-	1 843	5 808 793	3 152	10 226 049	5 549	1.88	59	415	7.47
Illinois Terminal	32 251	5.33	1 304	294	908 562	3 094	1 117 612	3 801	3.55	110	585	15.39
Lehigh Valley	18 586	9.83	-	1 770	5 589 585	3 158	7 073 979	3 997	0.33	11	103	2.59
Long Island	39 505	8.05	-	637	1 801 814	2 829	3 913 869	6 144	2.19	62	499	8.12

Maine Central	68 094	6.77	-	1 039	3 108 945	2 992	2 548 054	2 452	2.19	66	444	18.09
Missouri-Illinois	12 421	5.07	-	165	510 171	3 092	669 491	4 058	2.43	75	382	9.41
Monongahela	21 657	7.76	912	279	841 726	3 017	697 018	2 498	2.57	78	602	24.10
Norfolk & Western	932 848	7.07	-	12 187	37 913 919	3 111	124 608 030	10 225	2.46	77	541	5.29
Penn Central	1 788 131	6.97	26 696	34 166	102 840 800	3 010	249 119 880	7 291	1.74	52	365	5.00
Penna-Reading Seashore Lines	26 056	6.89	-	333	901 106	2 709	317 800	954	2.89	78	541	56.64
Pittsburgh & Lake Erie	37 434	8.20	631	567	1 734 185	3 059	2 646 727	4 668	2.16	66	541	11.60
Reading	130 027	6.15	-	2 155	5 933 641	2 754	8 880 602	4 121	2.19	60	371	9.01
Richmond, Fred'burg & Potomac	42 100	7.15	1 067	429	1 381 225	3 223	3 460 632	8 067	3.05	98	702	8.70
Western Maryland	50 801	7.66	-	1 120	3 250 318	2 902	6 723 677	6 003	1.56	45	347	5.79
Total Eastern District	4 872 828	6.88	49 566	87 796	263 528 367	3 002	640 673 455	7 297	1.85	56	382	5.23
SOUTHERN DISTRICT:												
Clinchfield	39 437	6.91	274	431	1 395 900	3 240	7 547 765	17 512	2.83	92	631	3.60
Florida East Coast e	153 910	7.52	-	1 010	3 044 553	3 015	5 431 963	5 378	5.06	152	1 147	21.32
Georgia	14 368	6.61	827	426	1 296 128	3 046	1 551 000	3 641	1.11	34	223	6.13
Illinois Central Gulf	1 163 071	6.02	51 292	12 850	40 773 470	3 173	78 807 998	6 133	2.85	91	545	8.89
Louisville & Nashville	580 708	5.72	10 692	9 527	27 475 530	2 884	85 859 768	9 012	2.11	61	349	3.87
Norfolk Southern	89 628	5.96	1 780	753	2 171 030	2 882	1 943 403	2 581	4.13	119	709	27.48
Seaboard Coast Line e	1 197 128	6.21	5 982	12 809	39 875 688	3 113	96 616 199	7 543	3.00	93	580	7.69
Southern System d	1 803 699	6.89	-	12 862	40 194 733	3 125	120 263 021	9 350	4.49	140	967	10.34
Total Southern District	5 041 949	6.40	70 847	50 668	156 227 032	3 083	398 021 117	7 855	3.23	100	637	8.10

Table A (Continued)

District and Road	Wooden cross ties laid in replacement			Track maintained by reporting railroad			Equated gross ton-miles (thousands)		New cross tie replacement averages			
	New ties		Second hand ties	Miles occupied by cross ties	Total cross ties	Cross ties per mile (1967)	Total	per mile of track	Percent renewal to all ties	Number laid per mile	Renewal cost per mile	Renewal cost per 1,000 GTM
	Number	Average cost										
	1	2	3	4	5	6	7	8	9	10	11	12
WESTERN DISTRICT:												
Atchison, Topeka & Santa Fe	1 347 678	$5.41	104 444	18 714	59 753 000	3 193	185 335 116	9 904	2.26	72	$390	3.93¢
Burlington Northern	1 526 575	6.15	22 789	30 450	92 537 550	3 039	195 148 431	6 409	1.65	50	309	4.81
Chicago & North Western	183 047	6.71	412 608	13 327	39 728 322	2 981	60 350 701	4 528	0.46	14	92	2.03
Chicago, Milw, St.Paul & Pac.	560 372	6.17	28 754	12 432	37 707 090	3 033	54 096 573	4 351	1.49	45	278	6.40
Chicago, Rock Island & Pacific	312 552	5.48	18 709	8 813	26 262 122	2 980	58 177 931	6 601	1.19	35	194	2.95
Colorado & Southern	47 827	5.61	281	729	2 229 653	3 060	5 621 146	7 711	2.15	66	369	4.79
Denver & Rio Grande Western	100 648	7.43	3 774	2 699	8 330 802	3 087	22 721 146	8 418	1.21	37	277	3.29
Duluth, Missabe & Iron Range	42 921	7.15	2 152	803	2 393 565	2 979	4 599 142	5 727	1.79	53	382	6.68
Duluth, Winnipeg & Pacific	23 099	6.58	-	205	592 871	2 890	2 245 609	10 954	3.90	113	741	6.77
Fort Worth & Denver	99 454	7.29	226	1 406	4 218 220	3 001	7 388 507	5 255	2.36	71	516	9.81
Green Bay & Western	1 635	6.47	13 299	302	871 171	2 880	855 866	2 834	0.19	5	33	1.17
Kansas City Southern (L&A)	322 190	6.61	-	2 269	7 259 849	3 199	19 390 041	8 546	4.44	142	938	10.98
Lake Superior & Ishpeming	832	7.21	1 169	174	523 470	3 000	74 570	429	0.16	5	34	8.05
Missouri-Kansas-Texas	202 532	7.35	-	2 538	8 131 498	3 204	15 797 188	6 224	2.49	80	586	9.42
Missouri Pacific	781 997	5.11	-	9 886	30 529 400	3 088	91 822 779	9 288	2.56	79	404	4.35
Northwestern Pacific	24 277	4.65	-	380	1 094 500	2 880	1 682 318	4 427	2.22	64	297	6.72
Oregon Electric	1 435	6.41	89	184	570 000	3 093	539 812	2 934	0.25	8	49	1.67
St. Louis-San Francisco	532 580	5.04	3 695	6 445	20 229 798	3 139	44 455 826	6 898	2.63	83	417	6.04
St. Louis Southwestern	190 282	7.32	55	1 688	5 169 174	3 063	31 801 035	18 839	3.68	113	825	4.38
Soo Line	176 848	5.36	36 932	5 276	15 868 961	3 008	23 106 989	4 380	1.11	34	180	4.10
Southern Pacific	805 405	5.05	-	16 357	48 253 817	2 950	213 577 142	13 057	1.67	49	329	2.52
Texas & Pacific	133 014	5.13	-	2 405	7 323 278	3 045	23 140 061	9 622	1.82	55	284	2.95
Texas Mexican	29 953	7.30	-	238	752 675	3 168	507 540	2 133	3.98	126	920	43.15
Toledo, Peoria & Western	7 396	5.85	-	295	933 451	3 168	1 249 537	4 236	0.79	25	146	3.44
Union Pacific	405 387	6.46	49 935	13 188	37 281 201	2 827	169 371 539	12 843	1.09	31	199	1.55
Western Pacific	82 067	9.78	-	1 790	5 342 557	2 985	16 447 166	9 188	1.54	46	449	4.88
Total Western District	7 942 003	6.02	698 911	152 993	463 887 995	3 032	1 249 503 711	8 167	1.71	52	313	3.83
Total United States	17 856 780	6.36	819 324	291 457	883 643 394	3 032	2 288 198 283	7 851	2.02	61	390	4.96
CANADIAN ROADS:												
Canadian National	1 141 421	6.10	-	30 340	89 138 700	2 938	-	-	1.28	38	229	-
Canadian Pacific	960 843	7.59	-	20 594	61 166 746	2 970	124 225 676	6 032	1.57	47	354	5.87
Ontario Northland	32 332	7.71	-	724	2 175 800	3 007	2 994 736	4 139	1.49	45	344	8.32

a - Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.

b - "Average cost" represents storekeepers' average cost of all kinds, sizes and grades of ties charged out and used rather than the average price of ties purchased during the year.

c - Column 4 based on cross ties per mile of track in 1967, the last year for which reported.

d - Includes all Southern System Class I Railroads.

e - Comprised of both other than wooden ties as follows:

District and Road	Other than Wooden ties		Wooden ties	
	Number	Average Cost	Number	Average Cost
Road				
Florida East Coast	26 070	$15.00	127 840	$6.00
Seaboard Coast Line	438	8.61	1 196 690	6.21
Kansas City Southern	2 127	12.55	320 063	6.57
District:				
Eastern District	-	-	4 872 828	6.88
Southern District	26 508	14.90	5 015 441	6.35
Western District	2 127	12.55	7 939 876	6.02
United States	28 635	14.74	17 828 145	6.35

Association of American Railroads, Economics and Finance Department, Washington, D. C. 20036
from Annual Reports of Class I Railroads to the Interstate Commerce Commission.

June 1974

Table B

NUMBER AND AGGREGATE COST OF NEW CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1969 to 1973 inclusive

Note: All figures are exclusive of switch and bridge ties

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in track					
	1969	1970	1971	1972	1973	5 year average	1969	1970	1971	1972	1973	5 year average	1969	1970	1971	1972	1973	5 year average
EASTERN DISTRICT:																		
Akron, Canton, & Youngstown	264	72	169	51	26	116	$1281	$425	$802	$313	$180	$600	8.94	2.44	5.72	1.74	.90	3.95
Ann Arbor	26	17	42	33	36	31	144	94	255	205	233	186	.86	.56	1.39	1.09	1.20	1.02
Baltimore & Ohio	54	52	66	52	44	54	267	277	394	307	260	301	1.87	1.78	2.27	1.81	1.51	1.85
Bangor & Aroostook	74	103	74	73	51	75	380	496	374	400	395	409	2.57	3.57	2.56	2.55	1.79	2.61
Bessemer & Lake Erie	66	44	50	114	102	75	430	306	368	835	927	573	2.19	1.46	1.68	3.81	3.39	2.50
Boston & Maine	24	28	39	66	79	47	135	158	297	439	555	317	.81	.95	1.34	2.22	2.68	1.60
Canadian Pacific (Lines in Me.)	20	7	96	46	37	41	69	30	554	251	254	232	.68	.24	3.28	1.57	1.26	1.41
Central RR of New Jersey	64	78	51	65	150	82	405	510	344	429	108	359	2.30	2.80	1.82	2.32	.58	1.96
Central Vermont	23	81	20	80	85	58	94	381	86	385	532	296	.79	2.82	.69	2.77	2.96	2.01
Chesapeake & Ohio	43	51	63	38	37	46	211	269	369	219	216	257	1.44	1.70	2.10	1.26	1.22	1.54
Chicago & Eastern Illinois	179	255	72	230	59	159	896	1206	363	1328	328	824	5.88	8.38	2.38	7.55	1.94	5.23
Delaware & Hudson	54	50	49	6	63	44	334	340	346	46	473	308	1.73	1.62	1.57	0.20	2.04	1.43
Detroit & Toledo Shore Line	-	-	45	52	4	34	1	-	359	269	29	165	.01	-	1.57	1.80	.13	.70
Detroit, Toledo & Ironton	17	28	37	46	53	36	88	161	216	307	355	225	.58	.98	1.29	1.60	1.85	1.26
Elgin, Joliet & Eastern	98	96	42	96	105	87	480	516	245	611	721	515	3.20	3.12	1.39	3.14	3.44	2.86
Erie Lackawanna	66	56	46	30	64	52	365	335	280	207	464	331	2.24	1.90	1.55	1.01	2.15	1.77
Grand Trunk Western	25	47	62	54	59	49	126	297	387	346	415	314	.78	1.50	1.96	1.71	1.88	1.57
Illinois Terminal	25	37	73	74	110	64	108	166	358	357	585	315	.82	.21	2.37	2.39	3.55	1.87
Lehigh Valley	1	3	11	4	11	6	3	13	47	33	103	40	.03	.09	.36	.14	.33	.19
Long Island	22	49	86	62	62	56	119	230	656	506	499	402	.77	1.75	3.02	2.19	2.19	1.98

Maine Central	61	64	74	64	66	66	312	338	424	419	444	387	2.05	2.15	2.46	2.16	2.19	2.20
Missouri-Illinois	60	97	75	61	75	74	255	456	369	291	382	351	1.94	3.13	2.41	1.96	2.43	2.37
Monongahela	31	10	45	23	78	37	201	70	324	180	602	275	1.04	.38	1.50	0.78	2.57	1.25
Norfolk & Western	57	89	66	75	77	73	327	562	388	448	541	453	1.84	2.86	2.11	2.40	2.46	2.33
Penn Central	37	37	49	53	52	46	198	212	284	342	365	280	1.24	1.24	1.63	1.75	1.74	1.52
Penna-Reading Seashore Lines	2	29	37	65	78	42	13	159	238	412	541	273	.08	1.06	1.37	2.40	2.89	1.56
Pittsburgh & Lake Erie	24	52	54	58	66	51	145	363	383	436	541	374	.80	1.72	1.76	1.89	2.16	1.67
Reading	58	41	59	68	60	57	304	245	333	378	371	326	2.11	1.49	2.13	2.47	2.19	2.08
Richmond Fred'burg & Potomac	107	226	175	126	98	146	595	1688	1224	886	702	1019	3.31	7.03	5.43	3.90	3.05	4.54
Western Maryland	45	55	62	47	45	51	254	337	389	307	347	327	1.55	1.88	2.14	1.62	1.56	1.75
Total Eastern District	46	51	55	55	56	53	246	291	329	345	382	319	1.54	1.69	1.85	1.83	1.85	1.75
SOUTHERN DISTRICT:																		
Clinchfield	74	47	79	88	92	76	400	299	539	612	631	496	2.27	1.46	2.45	2.73	2.83	2.35
Florida East Coast	115	102	311	30	152	142	1021	761	3238	286	1147	1291	3.81	3.38	10.30	0.99	5.06	4.71
Georgia	88	60	69	71	34	64	445	354	432	461	223	383	2.88	1.98	2.27	2.32	1.11	2.11
Illinois Central Gulf a	78	90	95	112	91	93	355	436	503	607	545	489	2.46	2.83	2.98	3.54	2.85	2.93
Louisville & Nashville b	72	83	98	51	61	73	311	588	485	259	349	398	2.49	2.87	3.39	1.75	2.11	2.52
Norfolk Southern	117	104	94	111	119	109	423	441	444	566	709	517	4.05	3.61	3.25	3.86	4.13	3.78
Seaboard Coast Line	103	101	116	117	93	106	503	524	651	675	580	587	3.32	3.23	3.72	3.74	3.00	3.40
Southern System	109	134	181	175	140	148	620	782	1118	1100	967	917	3.49	4.29	5.78	5.60	4.49	4.73
Total Southern District	93	103	126	115	100	107	470	545	746	675	637	615	3.02	3.34	4.10	3.74	3.23	3.49

Table B (Continued)

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in track					
	1969	1970	1971	1972	1973	5 year average	1969	1970	1971	1972	1973	5 year average	1969	1970	1971	1972	1973	5 year average
WESTERN DISTRICT:																		
Atchison, Topeka & Santa Fe	72	77	86	83	72	78	$308	$344	$419	$434	$390	$379	2.24	2.40	2.69	2.59	2.26	2.44
Burlington Northern c	36	37	40	46	50	42	168	195	227	285	309	237	1.18	1.20	1.31	1.51	1.65	1.37
Chicago & North Western	28	27	29	13	14	22	150	157	171	83	92	131	.95	.90	.96	.44	.46	.74
Chicago, Milwaukee, St. Paul & Pac.	61	44	48	55	45	51	310	245	274	324	278	286	2.03	1.45	1.60	1.81	1.49	1.68
Chicago, Rock Island & Pacific	59	66	72	71	35	61	268	308	341	340	194	290	1.97	2.22	2.42	2.37	1.19	2.03
Colorado & Southern	36	32	40	21	66	39	190	137	185	118	369	200	1.17	1.03	1.31	.70	2.15	1.27
Denver & Rio Grande Western	20	22	32	41	37	30	102	138	185	270	277	194	.66	.71	1.04	1.33	1.21	.99
Duluth, Missabe & Iron Range	32	42	29	39	53	39	206	265	186	261	382	260	1.09	1.41	.99	1.30	1.79	1.32
Duluth, Winnipeg & Pacific	39	80	23	155	113	82	214	433	133	1018	741	508	1.35	2.78	.80	5.34	3.90	2.83
Fort Worth & Denver	45	39	48	48	71	50	196	217	263	327	516	304	1.52	1.30	1.59	1.60	2.36	1.67
Green Bay & Western	d	5	22	26	5	15	d	24	109	141	33	77	d	.18	.77	0.91	.19	.51
Kansas City Southern	51	82	101	172	142	110	328	506	583	1005	938	672	1.59	2.58	3.15	5.37	4.44	3.43
Lake Superior & Ishpeming	3	8	1	1	5	4	13	37	7	7	34	20	.09	.26	.05	.05	.16	.12
Missouri-Kansas-Texas	88	69	75	80	80	78	414	369	414	446	586	446	2.74	2.15	2.33	2.51	2.49	2.44
Missouri Pacific	74	97	118	121	79	98	330	446	551	580	404	462	2.39	3.15	3.83	3.92	2.56	3.17
Northwestern Pacific	53	64	92	91	64	73	247	349	392	467	297	350	1.85	2.23	3.20	3.15	2.22	2.53
Oregon Electric	-	24	19	7	8	15	-	134	105	45	49	83	-	.77	.60	.23	.25	.46
St. Louis-San Francisco	68	69	75	96	83	78	267	288	351	454	417	355	2.18	2.20	2.40	3.07	2.63	2.50
St. Louis Southwestern	68	127	125	144	113	115	313	715	773	919	825	709	2.21	4.14	4.09	4.71	3.68	3.77
Soo Line	38	39	47	37	34	39	164	164	220	180	180	182	1.26	1.29	1.57	1.24	1.11	1.29
Southern Pacific	55	45	96	65	49	62	264	227	523	358	329	340	1.85	1.52	3.24	2.20	1.67	2.10
Texas & Pacific e	81	120	97	82	55	87	392	574	447	393	284	418	2.72	3.94	3.19	2.71	1.82	2.88
Texas Mexican	d	d	d	d	126	126	d	d	d	d	920	920	d	d	d	d	3.98	3.98
Toledo, Peoria & Western	80	71	75	109	25	72	397	395	453	673	146	413	2.52	2.24	2.38	3.45	3.79	2.88
Union Pacific	41	29	47	49	31	39	231	183	295	299	199	241	1.44	1.04	1.66	1.75	1.09	1.40
Western Pacific	72	57	57	46	46	56	539	470	492	417	449	473	2.40	1.92	1.92	1.55	1.54	1.87
Total Western District	52	52	64	59	52	56	246	264	339	326	313	298	1.70	1.72	2.10	1.94	1.71	1.83
Total United States	57	60	72	67	61	63	283	320	405	389	390	357	1.87	1.99	2.37	2.21	2.02	2.09
CANADIAN ROADS:																		
Canadian National	38	44	35	29	38	36	148	186	161	141	229	173	1.3	1.5	1.2	1.01	1.28	1.2
Canadian Pacific	65	57	57	58	47	57	303	300	357	333	354	329	2.19	1.94	1.94	1.95	1.57	1.92
Ontario Northland	60	33	33	53	45	45	341	188	192	288	344	271	2.02	2.02	1.19	1.92	1.49	1.73

a - Includes separate operations of Gulf, Mobile & Ohio merged August 10, 1972.

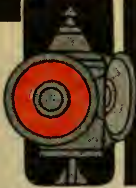
b - Includes separate operations of Monon merged July 31, 1971.

c - Formed by merger of Chicago, Burlington & Quincy, Great Northern, Northern Pacific and (by lease) Spokane, Portland & Seattle railroads effective March 3, 1970. Data shown for BN include separate operations of those roads for the periods prior to merger, (Merger did not include Oregon Electric and Oregon Trunk railroads which were included in SP&S report for the two months but which began separate reporting as Class I and Class II roads, respectively, effective March 1, 1970.)

d - Reported as a Class II railroad.

e - Includes separate operations of Kansas, Oklahoma & Gulf as a Class I railroad, merged with Texas & Pacific effective April 1, 1970.

STOP!



THINK UNIT

No overdriving

Effective on worn rail as well as new rail

Longer service life without shimming or reforming

No throat cutting of spikes

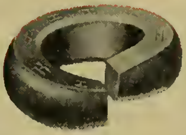
Suitable for machine or hand application

More Holding Power

Higher reapplication value

Less likelihood of damage to rail or anchors from derailed wheels

ALSO AVAILABLE—UNIT II. Same high quality at a lower cost... Made from a slightly lighter section of steel, for requirements where the very high holding power and reserve strength of the Standard Unit are not considered essential.



Hubbard Super Steel and Super Service Alloy TRACK SPRING WASHERS... manufactured to meet all current A.R.E.A. specifications.

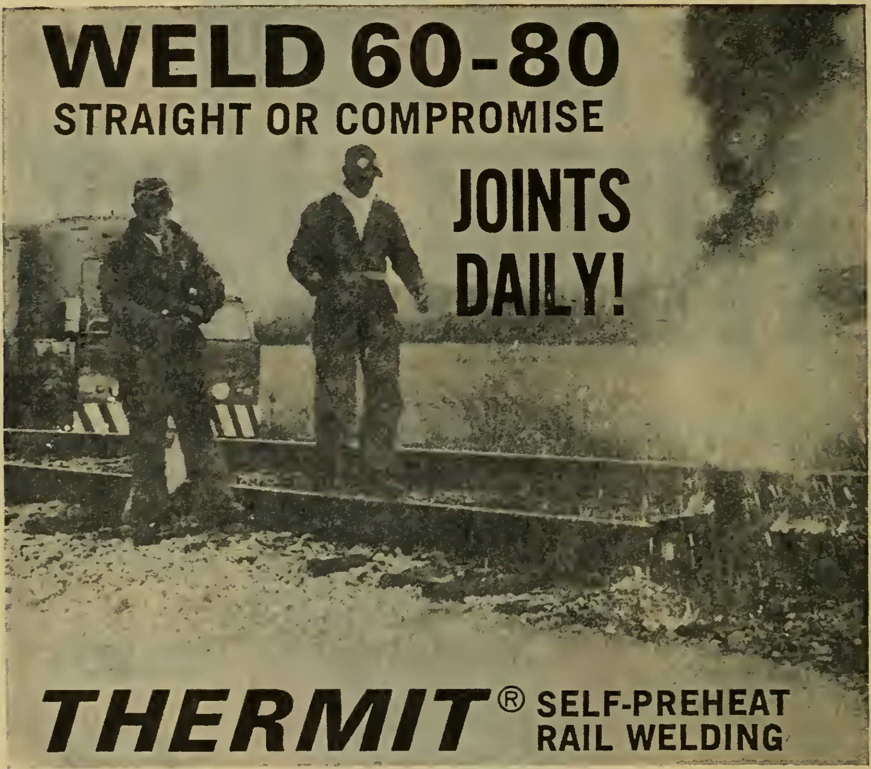
74UR1-A

MEMBER RPI RAILWAY PROGRESS INSTITUTE

UNIT RAIL ANCHOR COMPANY

P. O. Box 4004
Pittsburgh, Pa. 15201
(412) 781-4800

Midwest Office: 332 S. Michigan Ave.
Chicago, Ill. 60604
(312) 427-7442



THE MODERN IN-TRACK METHOD

- AUTOMATIC, **ERROR-FREE** PRE-HEATING AND TAPPING OF WELD METALS
- EASY, **COLD** REMOVAL OF RISERS
- MINIMUM GRINDING
- NO EQUIPMENT TO PURCHASE OR LEASE

FREE COMPLETE THERMIT RAIL WELDING DETAILS **PLUS** JOB-SITE DEMONSTRATIONS.

WRITE OR CALL

THERMIT®

THERMEX METALLURGICAL, INC.
LAKEHURST, N. J. 08733 • (201) 657-5781
SALES OFFICES IN MAJOR CITIES

Buying Channeloc®
is only the beginning.

It's true. And it may come as a surprise. But after a road has purchased and installed True Temper Channeloc, we send out field engineers to check installation and operation.

We don't closely examine each and every one, but our engineers are trained to spot a mis-installed Channeloc instantly and report such findings.

Such field checks are periodically performed on older installations, too. This way we get first-hand information on ageing performance for future application.

With True Temper Channeloc, you buy more than a rail anchor. You buy a continuing program of product research, performance, engineering and concern . . . concern that our products will work for you.

Don't settle for imitations. Only Channeloc is protected by U.S. Patent Nos. 3,102,690—3,118,327 — 3,159,198.

TRUE TEMPER®
An Allegheny Ludlum Industries Company

TIE HANDLER from RTW...

with 24-foot-reach articulating boom!

Lifting capacity—1500 lbs. at 12′6″ to 750 lbs. fully extended.

- New rotating deck design ...no adjustments needed
- Thermostatic controlled oil temperature in hydraulic circuit
- Low maintenance
- Hydrodynamic plus mechanical brakes... on all four wheels

Many other features for high production, low maintenance. Choice of two other tubular-type booms (all interchangeable): Fixed 24-ft., and manually adjustable 18-24-ft. From RTW, the people with the longest experience in tie handling. Get full details today. Call (215) 739-4281.

RTW

OTHER RTW MAINTENANCE EQUIPMENT • Switch Grinders • Cross Grinders • Surface Grinders • Rail Drills • Tie Handlers
RAILWAY TRACK-WORK CO. 2560 East Tioga St., Philadelphia, Pa. 19134
Agents: Chicago — ESCO Equipment Service Co. • Houston — Service Equipment & Supply Company
Los Angeles — Simkins Company • Louisville — T. F. Going • St. Louis — R. E Bell Co.
S. Plainfield, N. J. — Eastern Railroad Equipment Corp. • Canada: Montreal — Woodings-Canada Ltd.

MEMBER RPI RAILWAY PROGRESS INSTITUTE

M-1100 PORTABLE TURNOUT
increases productivity of men
and equipment up to 25%

Safetran
M-1100
TURNOUT TYPE SET-OFF

Keep equipment
where the work is.

•

Save fuel

•

Maintenance and servicing of equipment can be done at job site.

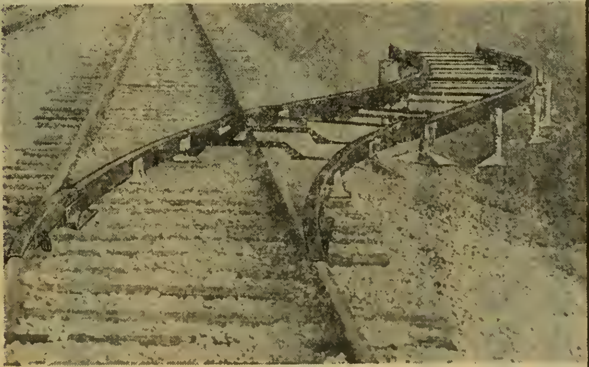
•

Easily assembled —can be assembled in 2 hours by 2 men.

•

Supports loads up to 60,000 lbs.

Turnout with points and frog removed for train passage.



Turnout assembled for M/W equipment set-off.

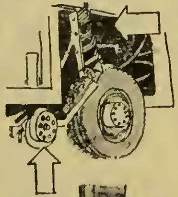
For operating data and specifications
see SAFETRAN M/W CATALOG—Section 16-J

Safetran Systems Corporation
7721 National Turnpike • Louisville, Ky. 40214 • (502) 361-1691

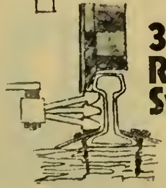
If you designed a perfect yard cleaner, you'd probably include these 5 features.

The Marmon Yard Patrol already has them.

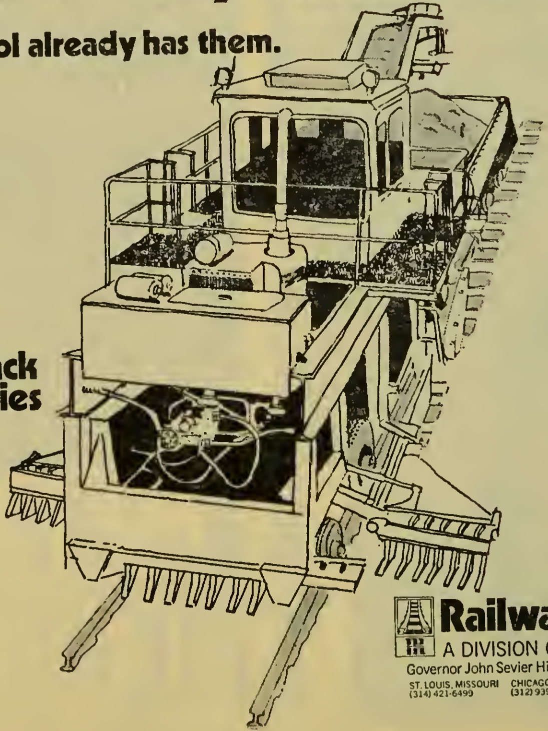
1. Side Discharge



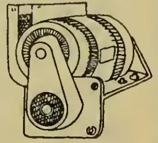
2. Off-track Capabilities

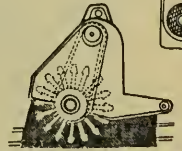


3. Rail web Sweeps



4. Electric Power for Rotary Functions





5. Protected Rear Broom

Railway Products Company
A DIVISION OF THE MARMON GROUP, INC.
Governor John Sevier Highway, P.O. Box 1511, Knoxville, Tennessee 37901 (615) 525-6224
ST. LOUIS, MISSOURI (314) 421-6499 CHICAGO, ILLINOIS (312) 939-0840 MONTREAL, QUEBEC (514) 637-2388 JACKSONVILLE, FLORIDA (904) 358-1828 CABLE: RAILPRO

You'll save time, trouble and money when you switch to PORTEC Track Equipment the leader in quality and delivery.

Ask your Portec man for details.
Or contact:

PORTEC inc.
300 Windsor Drive
Oak Brook, Illinois 60521
Telephone: 312/325-6300

MEMBER RPI RAILWAY PROGRESS INSTITUTE

In Canada: **PORTEC, LTD.**
500 Dominion Square Bldg.
Montreal, Quebec H3B1G4
Telephone: 514/866-9368

Portec Mark III Pak® Plastic Renewal Kits

Up to 10 times the service life of fibre insulation.

Portec-Bond® Insulated Rail Joints

Up to 980,000 lb. adhesive shear strength, with half the labor required to install other joints.

Portec Fair Rail Anchors

More sq. in. of tie bearing area than any other anchor. Installs faster, too.

Portec Poly-Insulated® Rail Joints

Rugged, urethane-encapsulated, heat-treated steel cores. Unexcelled performance.

Portec Portable Model 75 Heater

Faster, lower-cost curing of any bonded joint . . . with instant temperature read-out gauge. Unique!

Portec Rail & Flange Lubricators

Reduce costly friction wear. Overwhelming favorite of American Railroads.

Make tracks with the leader PORTEC inc.

EXPERIENCED SPECIALISTS IN THE REPAIRS OF.... RAILROAD STRUCTURES

Turzillo™ CORPORATION

FOUNDATIONS, UNDERPINNING AND INVESTIGATIONS

AUGERCAST®* Piles – placed without vibration
- For new foundations and underpinning
- Retaining wall piles. Low headroom piles
- Tie-back anchoring system for excavations
- Tension piles and anchors

PRESSURE GROUTING
- BAGPIPE®* Groutainer™ inflatable forming system
- Soil stabilization for arresting settlement of structures
- FIRM-UP® chemical grouting for consolidating soils
- Consolidating masonry bridge abutments and piers

CONCRETE AND MASONRY STRUCTURAL REPAIRS
- Bridges, dams, power plants and dry docks
- Scour repairs
- Tunnel lining repairs
- Repairs to precast, concrete, wood and steel piles

PREPLACED AGGREGATE CONCRETE (PAC)
- Cofferdam seals
- Underwater repairs, piers and abutments
- High density concrete for shielding
- Concrete and masonry structural repairs
- Underwater concrete

ONE-SOURCE MARINE SERVICES
- Inspections above and below water
- Engineering reports of inspections
- Staff of experienced divers to perform corrective repairs
- Submit budget or firm quotes
- Complete the work based on findings or at the direction of Owner's engineering department or consultant

* Covered by U. S. and Canadian Patents

P. O. BOX 155 • BRECKSVILLE, OHIO 44141 • TELEPHONE 216/659-3141
ATLANTA • BALTIMORE • CHICAGO • DETROIT • FT. LAUDERDALE • HOUSTON • JACKSONVILLE
MINNEAPOLIS • OMAHA • SEATTLE • TORONTO • TULSA
AFFILIATES: LEE TURZILLO CONTRACTING CO. • AUGERCAST PILE & FOUNDATION COMPANY
TURZILLO CONTRACTING LTD.

Turn Your Track Salvage
Into Extra Dollars
Allow Us To Quote Top
Prices For Your Surplus
Rail and Accessory Items.

CONTACT

VALIANT STEEL AND EQUIPMENT, INC.

P. O. BOX 17598

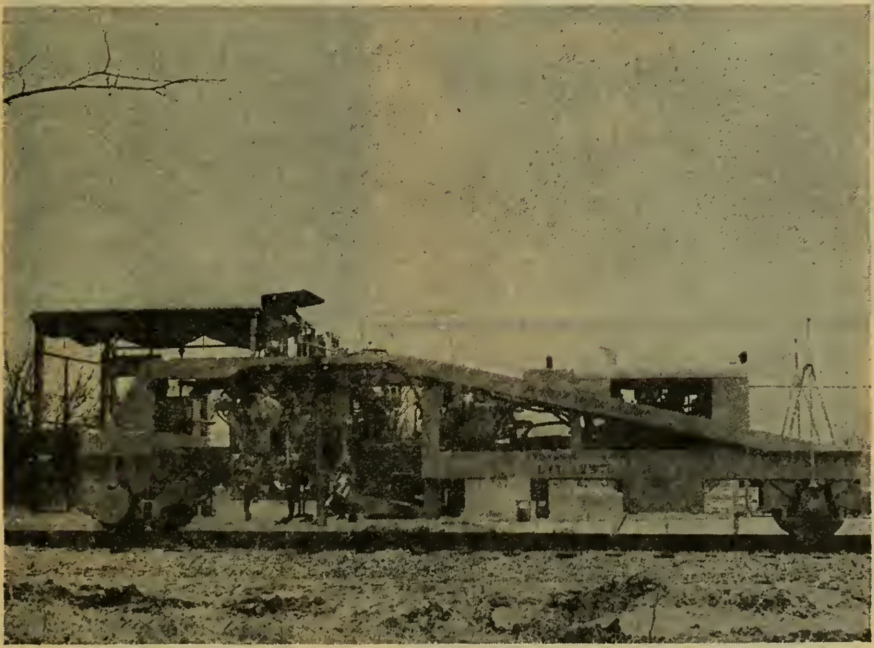
ATLANTA, GEORGIA 30316

Phone: (404) 243–3731 For Prompt Response

SWITCH TAMPERS FOR ALL YOUR JOBS

UNIVERSAL UYT-2W75 YARD, SWITCH & SPOT TAMPER

This versatile tamper is a new addition to the popular Plasser Universal line. Even though the UYT 2W75 has a lower original cost, it is equipped with two of the exclusive Plasser four-tool tamping heads with individually tiltable tamping arms, which insures the tamping of every tie through switches and turnouts without the use of outside or ground jacks.



This Universal UYT 2W75 tamper is particularly adaptable for yard work where it has proven itself as a money saver. The reasonable price plus its ability to do a fine job tamping switches and doing spot work suggest yard assignment. It can be equipped with automatic lifting and leveling equipment as well as automatic lifting correction with cross level indicator. You should see one of these tampers in service and we will be pleased to make the necessary arrangements for you to do so at your convenience. You will be convinced that it is a superior machine.

PLASSER AMERICAN CORPORATION

PLASSER FOR PERFORMANCE

GENERAL OFFICES & PLANT
2001 MYERS ROAD
CHESAPEAKE, VIRGINIA 23324

When You Consider Performance...

... Kershaw Comes First

KERSHAW MFG. CO., INC.
P. O. Box 9328
Montgomery, Ala. 36108 U.S.A.

- BALLAST REGULATOR
- TRACK PATROL
- SHOULDER EXCAVATOR
- UNDERCUTTER
- YARD CLEANER
- TRACK BROOM
- TRACK LINER
- JACK - ALL
- BALLAST CLEANER
- KLEAR-WAY BRUSHCUTTER
- KLEAR-WAY SNOW BLOWER
- TRACK PATROL BRUSHCUTTER
- SNOW SWITCH CLEANER
- TIE SAW
- TIE CRANE
- BRIDGE CRANE
- TIE BED SCARIFIER - INSERTER
- TIE INJECTOR
- TIE END REMOVER
- BRUSH KRIBBER
- CRAWLER ADZER
- DUAL KRIBBER
- DUAL ADZER

---

no matter how
you look at it
there is just
one toilet
that stands alone.
one toilet that
has gained
general acceptance
world wide.
one toilet familiar
to all who have ever
flown in an airplane,
traveled in a bus,
sailed in a boat,
or lived in a
recreational vehicle.
the one chemical
retention toilet
now available,
designed especially

to recognize
the rugged requirements,
for all your
sanitation needs:
  locomotive
  caboose
  work equipment . . .
the Vapor NEWMATIC* toilet,
the toilet used
by more than 40 railroads**
become *more* familiar,
write
Transportation Systems Div.
Vapor Corporation
6420 West Howard Street
Chicago, Illinois 60648
In Canada—
Vapor Canada Limited

VAPOR CORPORATION
TRANSPORTATION SYSTEMS DIVISION

*TM Monogram Industries, Inc.
**names furnished on request

What's he doing?

Drilling one of 12,000 inspection holes in this 1300' creosoted pine trestle

Why?

to locate internal decay and evaluate remaining timber strength.

That's what we mean by inspection and in-place treatment

OSMOSE

OSMOSE WOOD PRESERVING CO.
4915 MONONA DRIVE
MADISON, WISCONSIN 53716

A tradition of service . . .

- **Water Treatment Chemicals Protecting Diesel Cooling Systems and Steam Generators**
- **Weed and Brush Control Chemicals**
- **Fuel Oil Additives**
- **Pollution Control Chemicals and Consulting Services**
- **Wheel Flange Lubricators**

NALCO CHEMICAL COMPANY
180 N. MICHIGAN AVENUE ▫ CHICAGO, ILLINOIS 60601

NALCO Trademarks of Nalco Chemical Company

NALCO

KERITE CABLE

For dependability in actual use, no other cable matches Kerite. We believe you will be impressed by the evidence.

MEMBER RPI

THE KERITE COMPANY

PRINCIPAL OFFICES: Boston; Chicago; New York; Philadelphia; San Francisco; and Seymour, Connecticut • Sales Representation throughout the United States. A subsidiary of Harvey Hubbell Incorporated.

DAYS KERITE

it's the **KERITE** *insulation that makes the difference*

Nordberg

railway equipment

"ORGANIZED MECHANIZATION"
for lower track maintenance costs

1. SELF-PROPELLED ADZER
2. BALLAST ROUTER
3. HYDRA-SPIKER
4. LINE INDICATOR
5. PLATE PLACER
6. POWER JACK
7. TRACK WRENCH
8. RAIL DRILL
9. RAIL GANG SPIKER
10. RAIL GRINDERS
11. ONE MAN SCARIFIER AND INSERTER
12. SPIKE HAMMER
13. SPIKE PULLER
14. SPIKE STRAIGHTENER
15. SURF-RAIL GRINDER
16. SWITCHLINER
17. TRACK INSPECTOR
18. TIE DRILL
19. TIE SPACER
20. TRAKLINER®
21. DUN-RITE GAGER
22. TRACK SHIFTER
23. X-LEVEL INDICATOR

For right-of-way maintenance, Nordberg products are grouped into time-saving efficient working teams to stretch your track maintenance dollars. Write Rexnord, Railway Equipment Division, Box 383, Milwaukee, Wis. 53201.

Rexnord

Railway Equipment Division

HABCO

Satisfaction through service

Specialists and manufacturers in the field of vegetation control.

SOIL STERILANTS

GRANULES—HABCO HYCHLOR . . . HABCO 5H . . . HABCO 10K . . . HABCO 10T . . . HABCO BROMEX

LIQUIDS —CHLORATE-BORATE . . . HYVAR X . . . KARMEX . . . TELVAR . . . ATRATOL . . . PRAMITOL

CONTACT CHEMICALS

DACONATE . . . DACAMINE . . . 2,4-D's OF ALL KINDS

BRUSH CONTROL

AMMATE . . . HABCO 10B . . . ALL COMBINATIONS OF 2,4-D and 2,4,5-T

YOUR APPLICATION OR OURS

HABCO INCORPORATED

Our regional representatives are as close as your telephone.

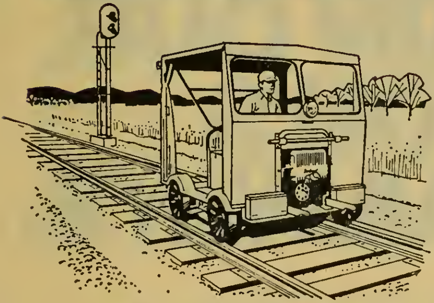
D. DOUGLAS BOATRIGHT
Room 604, Transportation Bldg.
Birmingham, Ala. 35203
205/252–6715

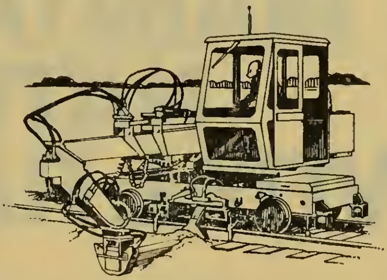
DON TELGE
JOHN FORDERHASE
2251 Armour Road
North Kansas City, Mo. 64116
816/421-1488

DONALD E. HORNE
JOHN A. FELLMAN
7301 W. Lake St.
Minneapolis, Minn. 55426
612/929-4689

ROBERT E. LUND
1040 Coulter
Winnipeg 3, Manitoba
204/783-3684

Fairmont
RAILWAY MOTOR CARS
AND WORK EQUIPMENT





INSPECTION MOTOR CARS
SECTION MOTOR CARS
GANG MOTOR CARS
PUSH CARS AND TRAILERS
HY-RAIL EQUIPMENT
BALLAST MAINTENANCE CARS
WEED MOWERS
MOBILE CRANES
TOW TRACTORS
RAIL GRINDERS
DERRICK CARS
HYDRAULIC POWER TOOLS
TRACK LINERS
TRACK LINING LIGHT
SPIKE DRIVERS
TIE REMOVERS
TIE HANDLERS
RAIL LIFTERS
TIE SHEARS
TIE BED SCARIFIERS
SPIKE PULLERS
TIE PLUG INSERTERS
OIL SPRAYERS
TIE SPRAYERS
TIE INSERTERS

Performance ON THE JOB COUNTS

THESE UNITS ARE ACTUATED EITHER COMPLETELY OR PARTIALLY BY HYDRAULIC POWER

FAIRMONT RAILWAY MOTORS, INC., FAIRMONT, MINNESOTA 56031

TO HELP YOU BUILD AND MAINTAIN OUR NATION'S VITAL RAILWAYS.

- Crushed slag
- Sand and gravel
- Ready mixed concrete
- Crushed stone
- Industrial sand
- Bituminous concrete
- "Enslag Colmix" (a bituminous paving mixture laid cold)

PRODUCTS PRODUCED TO MEET YOUR ENGINEERING SPECIFICATIONS.
Fast, on-schedule deliveries and streamlined production from more than 130 strategically located plant facilities.
Call Joe Lynch

Vulcan Materials Company
ONE OFFICE PARK, BIRMINGHAM, ALABAMA 35223; TELEPHONE 205/879-0421

VELSICOL®

**"THE NEW FORCE IN
VEGETATION CONTROL CHEMICALS"**

BANVEL®

The 3 E's herbicide

Efficacy—Banvel is a systemic.

Economy—Long-lasting and low cost.

Ecology—Relatively short persistence—established tolerances for many food crops and milk.

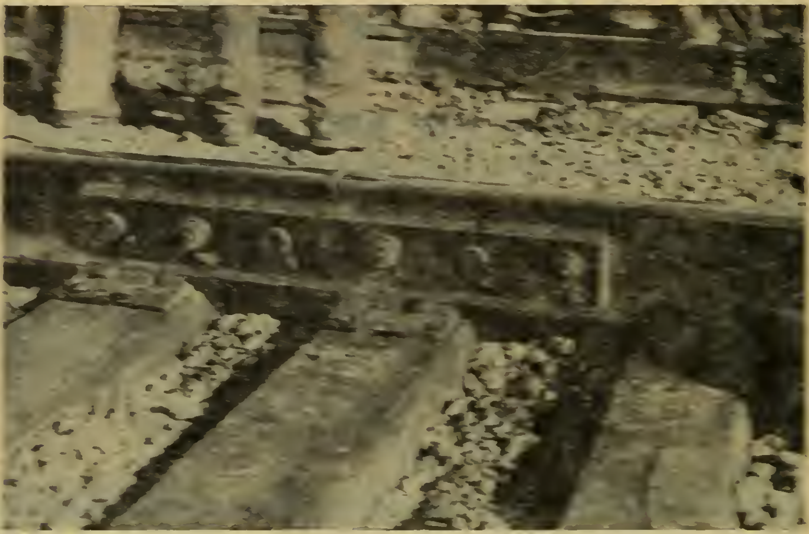
VEGATROL™

A full line of 2,4-D's and 2,4,5-T together with the Banvel line of herbicides, answers your unwanted Vegetation Problems.

ACCUTROL™ air emulsion SPRAY SYSTEM

- Low-volume Spraying
- Drift Reduction

VELSICOL CHEMICAL CORPORATION
341 East Ohio Street
Chicago, Illinois 60611



The Allegheny Insulated Rail Joint-

Designed to withstand the heaviest traffic in welded rail

This modern joint cements rail ends in position and thereafter resists all forces imposed by temperature and simultaneous forces of live loads to move them.

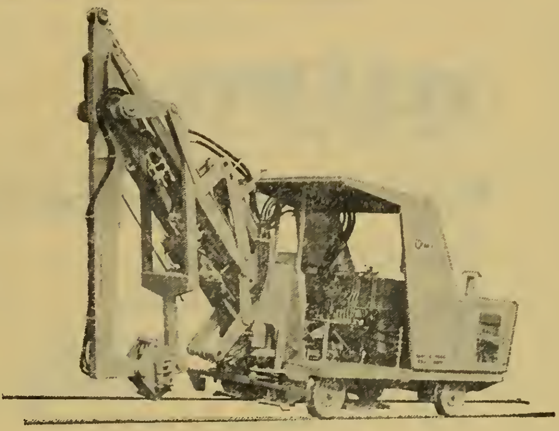
This joint makes welded rail truly continuous. It promises you years of service without maintenance costs. It reduces rail and wheel batter to a previously unknown minimum. It employs the safety of steel splice bars. It can be assembled in the shop or field. It has been tested in service and AAR laboratories. It saves you lots of money.

Allegheny Drop Forge Company

Subsidiary of Tasa Corporation

2707 Preble Avenue • Pittsburgh, Pa. 15233

When it comes to RAILWAY MAINTENANCE EQUIPMENT



We believe . . .

it is the responsibility of the manufacturer to design, build and operate if required, the equipment that will do the job easier, quicker and at less cost. Whether purchased, rented or leased, the equipment must justify the cost by performance . . . be safe in operation and travel . . . and make maximum use of track time schedules. Such a unit is the

MANNIX WOOD OR CONCRETE TIE INSERTER

Diesel powered with full view push button operation that enables one man to complete a full cycle (move and locate machine, pick tie off rails and insert) in as little as 12 seconds from either side. Boom is swung forward between rails in travel. Air operated brake shoes on all wheels. Hydraulic powered turn table set-off is standard equipment.

MEMBER RPI RAILWAY PROGRESS INSTITUTE

MANNIX RAILWAY MAINTENANCE EQUIPMENT FOR:
• Shoulder Ballast Cleaning • Raising Track • Resurfacing • Reballasting • Replacing Ties • Undercutting • Ballast Cleaning • Rail Grinding Single or Multiple track—Mainline or Yard tracks
CONTRACT, SALE or LEASE

FOR FULL DETAILS, OR SHOWING OF OPERATING FILMS, WRITE OR CALL TODAY

MANNIX

MAINTENANCE of WAY DIVISION
MANNIX CONSTRUCTION, INC.

3900 Arrowhead Road, Hamel, Mn 55340, U.S.A.

Phone (612) 478-6014
Telex 29-0391; Cable, MANNIX

TELEWELD
INC.

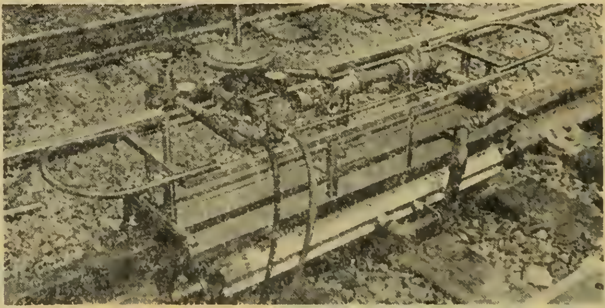
Rail Maintenance Service

Rail End Welding
Rail End Hardening
CWR Joint Normalizing
Frog and Switch Welding

MEMBER
RPI
RAILWAY PROGRESS INSTITUTE

Rail Maintenance Equipment

Custom Manufacturing and Fabrication
Joint Bar Shims
Rail Anchor Shims
Rail End and Frog and Switch
Welding and Grinding Machines
CWR Heating and Cooling Equipment
Rail Flaw Testing Equipment
Telebrineller Portable Hardness Tester



Infra-Red Heater for Curing Adhesive Bonded Rail Joints

TELEWELD INC., 416 NORTH PARK ST., STREATOR, ILL. 61364
Write for details of the TELEWELD process for restoring rail ends.

Advance Report of Committee 4—Rail
Report on Assignment 5

Rail Research and Development

W. J. Cruse *(chairman, subcommittee)*, B. G. Anderson, R. M. Brown, E. T. Franzen, R. E. Gorsuch, R. E. Haacke, V. E. Hall, W. H. Huffman, T. B. Hutcheson, K. H. Kannowski, W. S. Lovelace, A. B. Merritt, Jr., J. L. Merritt, C. O. Penney, I. A. Reiner, W. A. Smith.

Your committee presents its advance report on Assignment 5 in two parts, both as information. Part 1 is Association of American Railroads Research and Test Department Report No. R-160 (Project No. R048), "Metallurgical Examination and Physical Test Results of Chrominum and Manganese–Vanadium Alloy Rail Steel Investigation." Part 2, which begins on page 99, is Association of American Railroads Research and Test Department Report No. R-156 (Project No. R009), "Summary of Performance of Standard Carbon and Various Wear-Resistant Rails in Test Curves on the Chessie System." The author of both reports is K. W. Schoeneberg, senior research engineer at the AAR Technical Center, Chicago.

PART 1

METALLURGICAL EXAMINATION AND PHYSICAL TEST RESULTS OF CHROMIUM AND MANGANESE–VANADIUM ALLOY RAIL STEEL INVESTIGATION

K. W. SCHOENEBERG

Abstract

This report contains the results of metallurgical examinations and laboratory accelerated testing of samples of chromium and manganese-vanadium rail to determine the quality and strength of these types of rail steel.

The rail samples, for purposes of this investigation, of both types of rail were furnished to the AAR Technical Center by the Canadian Pacific Limited.

The investigation consisted of rolling-load tests, drop tests, slow bend tests, physical property determinations, charpy impact tests, chemical analysis, hardness surveys and macroscopic and microscopic examinations conducted at the AAR Technical Center, Chicago.

Introduction

As part of the programs on rail research, the AAR Research and Test Department is continuing metallurgical examinations and laboratory accelerated testing of samples of new or different types of rail. This work is conducted on rails having variables of heat treatment, chemical composition or processing method of manufacture to determine the quality and strength of the rail steel.

Promising alloy additions, variations in chemistry and heat treatment or variance in the manufacturing process could produce appreciable rail service life extension. Laboratory testing and metallurgical analysis are intended to show if these types of rail merit further evaluation or use in track.

ACKNOWLEDGEMENT

Appreciation is hereby acknowledged for the cooperation of W. A. Smith, chief engineer, Canadian Pacific Limited, in arranging to furnish the samples of the two types of rail to the Technical Center for this investigation. All other costs involved in this investigation were borne by the Association of American Railroads as part of its continuing efforts of rail research. The laboratory work was conducted by D. H. Stone, senior research metallurgist, H. B. Johnson, assistant metallurgical engineer and C. Somogy, assistant research engineer.

DESCRIPTION OF TEST SPECIMENS

For this evaluation, six rail samples, each 6 ft (1.83 m) in length, of 132 RE chromium rail and six rail samples, each 6 ft (1.83 m) in length of 132 RE manganese-vanadium rail were used. These rail samples were cut from 39-ft (11.89-m) lengths of new rail, one of each type, purchased by and for use in track of the Canadian Pacific. The chromium rail was produced from heat No. C.R. 48536 and rolled in February 1972 from ingot No. 18, rail letter G. The manganese-vanadium rail was produced from heat No. E 4516 and rolled in June 1971 from ingot No. 1, rail letter B.

The rail samples, or specimens, were identified for purposes of testing and metallurgical examinations as follows:

Chromium Rail—C.R. 48536 G 18

Rail Cut Number	*Specimen Number*
1	H-C-C1
2	H-C-C2
3	H-C-C3
4	H-C-12-1
5	H-C-A
6	H-C-B

Manganese-Vanadium Rail—E 4516 B 1

Rail Cut Number	*Specimen Number*
1	M-V-C1
2	M-V-C2
3	M-V-C3
4	M-V-12-1
5	M-V-A
6	M-V-B

RESULTS OF TESTS AND EXAMINATIONS

An outline of the tests and examinations conducted at the AAR Technical Center on these rail specimens is as follows:

Specimen Number	*Test or Examination*
H-C-C1	RL(C)
H-C-C2	RL(C)
H-C-C3	RL(C)
H-C-12-1	RL(12)
H-C-A	SB
H-C-B	D, P, I, H, C, MA(L) MA(T), MI(CL), MI(GS)
M-V-C1	RL(C)
M-V-C2	RL(C)

Specimen Number	*Test or Examination*
M-V-C3	RL(C)
M-V-12-1	RL(12)
M-V-A	SB
M-V-B	D, P, I, H, C, MA(L) MA(T), MI(CL), MI(GS)

Key to Symbol Designations

RL(C)—Rolling-Load Test (Cradle-Type Machine)
RL(12)—Rolling-Load Test (12-In-Stroke Machine)
SB—Slow Bend Test
D—Drop Test
P—Physical Property Determination
I—Charpy Impact Test
H—Hardness Survey
C—Chemical Analysis
MA(L)—Macroetch Test (Longitudinal Section)
MA(T)—Macroetch Test (Transverse Section)
MI(CL)—Microscopic Examination (Cleanliness Determination)
MI(GS)—Microscopic Examination (Grain Size Determination)

Rolling Load Tests

A 36-in (914-mm) long piece cut from rail specimens H-C-12-1 and M-V-12-1 was fatigue-tested in the 12-in (305-mm) stroke rolling-load machine. In this test a cantilever loading arrangement is used as shown diagrammatically in Fig. 1. As noted in this diagram, the rail specimens are tied down to the machine bed at one end of the rail. A wheel load of 57,500 lb (255,773 N) was used in testing both types of rail specimens. With this wheel load, a maximum bending moment of 575,000 in-lb (64,966 Nm) is developed at the point 2 in (50.8 mm) beyond the front support. Using this loading arrangement, the outer longitudinal fibers in the rail head at the point 2 in (50.8 mm) beyond the front support were subjected to cyclic stressing ranging from 0 to 25,555 psi (175.81 MPa) tension. An acceptance criterion of 2,000,000 cycles without failure is used for this test and both of these rail specimens withstood that number of cycles of repeated loading without failure. A summary of these rolling-load test results is presented in Table 1A.

Four 14⅞-in (377 mm) long pieces were cut from rail specimens M-V-C1, M-V-C2, M-V-C3 and H-C-C2 and tested in the 7-in (178-mm) stroke cradle-type rolling-load machines. Two 19⅞-in (505 mm) long pieces were cut from rail specimens H-C-C1 and H-C-C3 and tested in the 12-in (305-mm) stroke cradle-type rolling-load machine. These machines were designed to induce shelling in rail by the application of a heavy rolling load to the top and gage corner of the rail head. The loading arrangement used in the cradle-type rolling-load machines is shown diagrammatically in Fig. 2. In these tests the base of the rail is placed solid on the cradle bed and the cradle rotates approximately 13 deg (0.23 rad) from the vertical. As the cradle rotates, the wheel passes over the gage corner of the rail. A wheel load of 50,000 lb (222,411 N) was applied. All six of the rail specimens ran to 5,000,000 cycles. In this type of test, 5,000,000 cycles without developing a visible shell is considered a runout.

To determine whether any internal crack or shell developed in the head of the rail specimen during testing, each rail was monitored by ultrasonic detection equipment. By this means, the initiation and propagation of any crack or metal separation in the rail head could be noted and plotted. A small internal shell was detected under the gage corner in rail specimen H-C-C1 and a longitudinal internal crack or stringer was detected in rail specimen M-V-C1. The recording and plotting of these are shown diagrammatically in Fig. 3. Figs. 4 through 7 show cross section and side views of two rail samples after the rolling load tests. A summary of the cradle-type rolling test results is presented in Table 1B.

Drop Tests

Drop tests were performed on rail specimens M-V-B and H-C-B. The rail specimens were tested in accordance with AREA Specification 4–2–3, paragraph 7, which states that rails tested head upward on supports 4 ft (1.22 m) apart, shall withstand one blow of a 2,000-lb (8896-N) tup dropped from a height of 22 ft (6.70 m). Both of these rail specimens withstood five blows each without breaking. A summary of the drop test results is shown in Table 2.

Slow Bend Tests

Rail specimens M-V-A and H-C-A, were subjected to a slow bend test. This test was made on a support 4-ft (1.22 m) apart with a two-point loading applied 6 in (152.4 mm) on each side of a center line drawn midway between the supports. These tests were made with the rail base down which subjects the head to a compressive stress and the base to a tension stress. A diagram showing the loading arrangement used in this slow bend test can be found in Fig. 8. Rail specimens M-V-A and H-C-A were taken to 4.95 in (125.7 mm) of deflection under a 611,400 lb (2,719,643 N) and 561,800 lb (2,499,011 N) load, respectively, with both rails breaking at that point. The modulus of rupture was calculated to be 199,400 psi (1374.81 MPa) for specimen M-V-A and 183,196 psi (1263.09 MPa) for specimen H-C-A. Photographs showing the side view and fracture faces of these test specimens can be seen in Figs. 9, 10, 11 and 12. Table 3 is a summary of the slow bend test results of these rail steels. This table also gives typical slow bend test results for standard carbon rail of 132 RE section for comparison.

Physical Property Determinations

To determine the physical properties of both of these types of rail steels, two tensile bars each were taken from the head of specimens M-V-B and H-C-B. These tensile bars were cut from an area representing the mean location in the rail steel bloom. A Baldwin Universal Testing Machine with a 120,000-lb (533,787-N) capacity was used to pull these tensile bars. The physical properties determined were ultimate tensile strength, yield strength, reduction of area and elongation. The yield strength was obtained with the use of an extensometer and using a 0.2 percent offset according to the offset method described in ASTM A 370–68. A summary of the physical property test results can be found in Table 4. This table also gives physical properties of standard carbon steel rails obtained in past testing, for comparative purposes.

Charpy Impact Tests

Standard charpy V-notch specimens were cut from the head of specimens M-V-B and H-C-B. These specimens were cut longitudinally to the rail, which is in the direction of rolling. Three impact specimens were tested at 40 F (22.2 C) temperature increments between +40 F (4.4 C) and +240 F (115.5 C) degrees in a Riehle impact tester. A summary of the impact values obtained from each rail specimen is reported in Table 5. Plots of these impact values at each temperature are shown in Figs. 13 and 14. The bands noted in these plots represent the limits of impact values.

Two additional sets of charpy specimens from each of the rail steels were fatigue-cracked at their notch roots and subjected to an instrumented impact test. This was to determine the dynamic fracture toughness, K_{Id}, between temperatures of —3 F (—19.5 C) and 185 F (85 C) degrees at a strain rate of approximately 10^3/sec. A summary of these values obtained for each type of rail steel is shown in Table 6.

The values of the dynamic fracture toughness, K_{Id}, versus temperature is presented in Figure 15. If the K_{Id} is known, the stress to propagate a brittle fracture from a given size crack may be calculated from the equation:

$$\sigma_f = K_{Id}\sqrt{\frac{f(g)}{\pi a_c}}$$

where σ_f = fracture stress
K_{Id} = dynamic fracture toughness
$f(g)$ = defect geometry function (usually 1.1)
a_c = depth of critical crack
$\pi = 3.1416$

These data show that the manganese-vanadium rail steel has fracture properties comparable to standard carbon rail steel manufactured to the AREA specified chemical composition while the chromium rail steel has a toughness level about 10 ksi $\sqrt{\text{in}}$ (11 $\text{MNm}^{-3/2}$) lower. This indicates that, with the same size crack, the manganese-vanadium rail could tolerate a stress that is approximately 45 to 50 percent higher than could a chromium rail without fracture. Under the same stress conditions, the critical crack size in a manganese-vanadium rail would be about two times larger than the critical crack size in the chromium rail.

Chemical Analysis

A check chemical analysis was made by a commercial laboratory on rail specimens M-V-B and H-C-B. These analyses were made on drillings taken from the rail head area. A summary of the check analyses results, Table 7, shows the higher content of manganese and addition of vanadium alloy to the manganese-vanadium rail and the higher chromium content of the chromium rail.

Hardness Survey

A hardness survey was made over the cross section of a transverse section cut from rail specimens M-V-B and H-C-B. Hardness readings were obtained with a Brinell Hardness tester using a 3,000 kg load. The range of hardness readings obtained from these specimens is as follows:

Specimen No.	*Range of Hardness Readings (B.H.N.)*
M-V-B	317–351
H-C-B	300–334

A sketch showing the locations checked and the hardness values obtained can be found in Figs. 16 and 17.

Macroscopic Examinations

To determine the soundness of both types of the rail steels, transverse sections were cut from rail specimens M-V-B and H-C-B and macroetched in a hot 50 percent aqueous solution of hydrochloric acid. Internal conditions such as light center segregation and scattered porosity throughout the rail cross-section with an irregular pattern porosity in the head and base were noted in the manganese-vanadium rail. This can be seen in Fig. 18. The chromium rail was noted to be sound with only slight scattered center porosity as shown in Fig. 19.

To determine whether there were any shatter cracks or hot torn steel in these rails, longitudinal sections were cut from the heads of both rail samples and etched in a hot 50 percent aqueous solution of hydrochloric acid. An examination of these macroetched longitudinal sections showed that the manganese-vanadium rail had slight streak segregation while the chromium rail displayed a moderate to high amount of streak segregation. Both samples revealed no shatter cracks or hot torn steel. Photographs of these longitudinal sections are shown in Figs. 20 and 21.

A summary of the findings from these macroscopic examinations can be found in Tables 8A and 8B.

Microscopic Examinations

To view the grain structure of these rail steels, specimens were cut from rail specimens M-V-B and H-C-B for a microscopic examination. These specimens were taken so as to examine the plane transverse to the direction of rolling. The specimens were etched with a 2 percent nital solution and examined at a magnification of 100X. In examining the manganese-vanadium and the chromium specimens, the structures viewed were both of a composition consisting of only equiaxed pearlitic grains but differing slightly in grain size. For the manganese-vanadium rail steel the grain size was estimated to range from 4½ to 7 with 6 being predominant. The chromium rail steel showed a grain size of 3½ to 6½ with 5 being predominant. These grain sizes were determined by comparison of photomicrographs with ASTM chart, Designation E-112, Plate 1. Photomicrographs of these two rail steel grain structures are shown in Figs. 22 and 23. A summary of the findings from this microscopic examination can be found in Table 9A.

Steel cleanliness was established on specimens cut from the same rail specimens. The specimens used in this examination were taken so as to view the plane in the direction of rolling. These specimens were unetched and examined at a magnification of 100X. In examining these specimens, non-metallic inclusions of the sulfide, silicate and oxide types were found in the manganese-vanadium rail steel and non-metallic inclusions of sulfide, silicate, oxide and alumina types were found in the chromium rail steel. These inclusions were rated by comparison with ASTM chart Designation E-45, Plate 1. A summary of cleanliness ratings can be found in Table 9B. Photomicrographs showing the cleanliness in these specimens are shown in Figs. 24 and 25.

CONCLUSIONS

This evaluation of rails made with alloy elements of chromium, manganese and vanadium submitted to the AAR Research and Test Department by the Canadian Pacific Limited resulted in the following conclusions:

1. The rolling-load tests conducted in the 12-in (305-mm) stroke rolling-load machine on the two rail type specimens ran 2,000,000 cycles of repeated loading without failure. These are results comparable to those obtained in testing standard carbon rails.

2. The six rail specimens, three of each type of rail, subjected to the cradle-type rolling-load test, which is designed to study the resistance of the rail to shelling, ran to completion of 5,000,000 cycles without developing a visible shell. Through monitoring these rails during testing by ultrasonic detection equipment, the initiation and propagation of a small internal shell was detected in one chromium rail specimen and a longitudinal internal crack or stringer was detected in one manganese-vanadium rail specimen. These did not break out on the gage side of the rail head as a visible shell crack. The average number of cycles required to develop a shell in standard carbon rail has been determined to be 1,402,493 cycles at 50,000 lb (222,411 N) applied wheel load. This was calculated from the results of 33 cradle-type rolling-load tests on standard carbon rail (all sections) as reported in the AREA Proceedings from the years 1949 through 1965.

3. The manganese-vanadium rail specimen and the chromium rail specimen which were subjected to the drop test both withstood five blows without breaking. This meets the AREA requirements of withstanding one blow of the tup.

4. The two rail specimens, one of each type, subjected to slow bend testing were taken to 4.95 in (125.7 mm) of deflection and both rails broke at that point. The manganese-vanadium rail was under a 611,400-lb (2,719,643-N) load at that breaking point and had developed a modulus of rupture of 199,400 psi (1374.81 MPa). The chromium rail was under a 561,800-lb (2,499,011-N) load at the breaking point and had developed a modulus of rupture of 183,196 psi (1263.09 MPa). These load and modulus of rupture values are 21 and 11 percent higher, respectively, in comparison to data obtained for standard carbon rail of the same section as noted in Table 3. This indicates that the chromium and the manganese-vanadium rail steels are somewhat stronger.

5. The physical properties of the manganese-vanadium rail steel and the chromium rail steel show higher average values of ultimate tensile strength of 21 percent, yield strength of 35 percent, and hardness of 11 percent over those of standard carbon rail steel as noted in Table 4. This should give these rails a wear and metal flow resistance superior to that of standard carbon steel rails.

6. Charpy V-notch impact values were found to be comparable and generally characteristics of standard carbon rail steels. The dynamic fracture toughness values indicate that the manganese-vanadium rail steel has fracture properties comparable to standard carbon rail steel while the chromium rail steel has a lower toughness level. This indicates that the manganese-vanadium rail could tolerate a higher stress than could a chromium rail without fracture. Under the same stress conditions, the critical crack size would be larger in the manganese-vanadium rail than it would be in the chromium rail.

7. The check chemical analysis indicates that for the elements of carbon, manganese, phosphorus, sulfur and silicon, both rail steels are within the AREA specified requirements except for the additional manganese in the manganese-vanadium rail steel and 0.02 percent above the limits for silicon in the chromium rail steel.

8. Hardness values obtained range well above those usually obtained for standard carbon steel rail, showing the effect of the alloy elements.

9. A macroscopic examination of the transverse sections showed light center segregation and scattered porosity with an irregular pattern porosity in the manganese-vanadium rail and only slight center porosity in the chromium rail. An examination of the macroetched longitudinal sections showed both types of rail steel with streak segregation but no shatter cracks or hot torn steel. The overall quality of both of these rail steels is similar to that of standard carbon rail steel.

10. The microscopic examinations of the grain structure revealed that both types of rail steel were of a composition consisting of equiaxed pearlitic grains and differing slightly in grain size. An examination of the steel cleanliness of both rail steels showed a moderate number of sulfide, silicate and oxide inclusions in the manganese-vanadium steel and a moderate number of sulfide, silicate, oxide and alumina inclusions in the chromium steel.

ANSI-SI Conversion Table
(Taken From ASTM E 380)

To Convert From	*To*	*Multiply By*
Inch (in)	Metre (m)	2.540 000 E—02
Foot (ft)	Metre (m)	3.048 000 E—01
Pound-Force	Newton (N)	4.448 222 E+00
Pound-Force-Inch	Newton Metre (Nm)	1.129 848 E—01
Pound-Force-Foot	Newton Metre (Nm)	1.355 818 E+00
Pound-Force-Inch^2 (psi)	Pascal (Pa)	6.894 757 E+03
KSI$\sqrt{in}$	Mega Newton Metre (MNm$^{-3/2}$)	1.1

TABLE 1A

ROLLING LOAD TEST RESULTS (12 IN. (305 mm) STROKE MACHINE)

Specimen No.	Rail Section	Wheel Load (lb.)	Wheel Load (N)	Number of Cycles	Remarks
M-V-12-1	132 RE	57,500	255,773	2,000,000	Rail did not fail - Runout
H-C-12-1	132 RE	57,500	255,773	2,000,000	Rail did not fail - Runout

TABLE 1B

ROLLING LOAD TEST RESULTS (CRADLE TYPE MACHINE)

Specimen No.	Rail Section	Wheel Load (lb.)	Wheel Load (N)	Number of Cycles	Remarks
M-V-C1	132 RE	50,000	222,411	5,000,000	Longitudinal crack noted (see Figure 3)
M-V-C2	132 RE	50,000	222,411	5,000,000	Did not develop shell
M-V-C3	132 RE	50,000	222,411	5,000,000	Did not develop shell
H-C-C1	132 RE	50,000	222,411	5,000,000	Small internal shell noted (see Figure 3)
H-C-C2	132 RE	50,000	222,411	5,000,000	Did not develop shell
H-C-C3	132 RE	50,000	222,411	5,000,000	Did not develop shell

TABLE 2

DROP TEST RESULTS

Specimen No.	Rail Section	Method of Testing	Distance Between Supports	Height of Drop	Number of Blows	Remarks
M-V-B	132 RE	Head Up	4 Ft. (1.22 m)	22 Ft. (6.70 m)	Withstood 5 Blows	Did not fail
H-C-B	132 RE	Head Up	4 Ft. (1.22 m)	22 Ft. (6.70 m)	Withstood 5 Blows	Did not fail

TABLE 3

SLOW BEND TEST RESULTS

Specimen No.	Max Load		Max Def.		Energy At Max. Def.		Modulus of Rupture		Remarks
	(lb.)	(N)	(in.)	(mm)	(ft. lb.)	(Nm)	(psi)	(MPa)	
M-V-A	611,400	2,719,643	4.95	125.7	224,333	304,155	199,400	1374.81	Broke
H-C-A	561,800	2,499,011	4.95	125.7	201,333	272,971	183,196	1263.09	Broke
Standard*	505,000	2,246,352	5.00	127.0	170,450	231,099	164,650	1135.22	Did not break

*Typical slow bend test results for standard carbon rail of 132 RE sections, as presented on page 315 of Volume 72, 1971 AREA Proceedings, included for comparison.

TABLE 4

PHYSICAL PROPERTIES

Specimen No.	Ultimate Tensile Strength (psi)	Ultimate Tensile Strength (MPa)	Yield Strength (psi)	Yield Strength (MPa)	Reduction of Area (%)	Elongation (%)	B. H. N.
M-V-B-1	161,550	1113.85	98,150	676.72	21.2	9.9	311
M-V-B-2	165,050	1137.98	101,650	700.85	22.4	10.5	319
H-C-B-1	154,400	1064.55	87,700	604.67	15.6	8.6	300
H-C-B-2	168,750	1163.49	102,050	703.61	23.9	9.7	302
Standard*	134,200	925.28	73,000	503.32	17.3	7.7	277

Two tensile bars were cut from each head of rail specimens M-V-B and H-C-B. These tensile bars were identified 1 and 2.

*Reference to AREA Proceedings Vol. 61, page 875, physical properties results of testing 132 RE standard carbon steel rail, for comparative purposes.

TABLE 5

RESULTS OF CHARPY IMPACT TESTS

(V-NOTCH)

Temperature		Rail Specimen M-V-B Impact Values						Rail Specimen H-C-B Impact Values					
(°F)	(°C)	Test 1		Test 2		Test 3		Test 1		Test 2		Test 3	
		(ft. lb.)	(Nm)	(ft. lb.)	(Nm)	(ft. lb.)	(Nm)	(ft. lb.)	(Nm)	(ft. lb.)	(Nm)	(ft. lb.)	(Nm)
+ 40	+ 4	3.0	4.1	3.5	4.7	3.0	4.1	7.5	10.2	6.0	8.1	6.5	8.8
+ 80	+ 27	3.5	4.7	3.5	4.7	5.5	7.5	8.5	11.5	5.5	7.5	5.5	7.5
+ 120	+ 49	3.5	4.7	2.5	3.4	4.0	5.4	6.0	8.1	8.0	10.8	5.5	7.5
+ 160	+ 71	5.0	6.8	6.0	8.1	4.0	5.4	8.5	11.5	9.0	12.2	9.0	12.2
+ 200	+ 93	7.0	9.5	5.5	7.5	5.5	7.5	8.5	11.5	7.5	10.2	6.5	8.8
+ 240	+ 116	8.0	10.8	7.5	10.2	8.0	10.8	9.0	12.2	9.0	12.2	8.5	11.5

TABLE 6

RESULTS OF FRACTURE TOUGHNESS TESTS

Specimen	Temperature		Dynamic Fracture Toughness K_{Id}	
No.	°F	°C	KSI $\sqrt{\text{in.}}$	$\mathrm{MNm}^{-3/}$
M-V-B				
1	32	0	24.0	27.0
2	75	24	26.0	28.0
3	136	58	31.0	34.0
4	186	85.5	34.0	38.0
H-C-B				
1	-5	-21	17.0	19.0
2	72	22	18.5	20.0
3	135	57	21.0	22.5
4	176	80	28.5	29.5
Standard Carbon				
1	-40	-40	22.0	24.0
2	0	-18	24.0	27.0
3	32	0	26.0	29.0
4	75	24	26.5	29.0
5	122	50	30.0	33.0
6	212	100	39.0	40.0

TABLE 7

CHEMICAL COMPOSITION

	Chemical Analysis (Percent)		
	Rail Specimens		
Elements	M-V-B	H-C-B	AREA Specification Requirements (Percent)
Carbon	0.69	0.72	0.69-0.82
Manganese	1.83	0.78	0.70-1.00
Phosphorus	0.006	0.012	0.04 (Max)
Sulfur	0.035	0.029	0.05 (Max)
Silicon	0.24	0.27	0.10-0.25
Nickel	< 0.05	0.05	
Chromium	0.59	1.31	
Molybdenum	< 0.05	< 0.05	
Copper	< 0.05	< 0.05	
Vanadium	0.12	--	
Aluminum	< 0.01	0.020	

The above analysis was made by a commercial laboratory.

TABLE 8A

MACROSCOPIC EXAMINATION

(TRANSVERSE SECTIONS)

MACRO ETCH TEST CONDUCTED TO DETERMINE INTERNAL QUALITY

Specimen No.	Etchant	Visual Examination
M-V-B	50% Aqueous Solution of Hydrochloric Acid	Light center segregation with scattered porosity throughout the rail cross-section with an irregular pattern porosity (see Figure 18)
H-C-B	50% Aqueous Solution of Hydrochloric Acid	Slight scattered center porosity. (see Figure 19).

TABLE 8B

MACROSCOPIC EXAMINATION

(LONGITUDINAL SECTIONS)

MACRO ETCH TEST CONDUCTED TO DETERMINE SOUNDNESS AND DISCLOSE THE PRESENCE OF SHATTER CRACKS

Specimen No.	Etchant	Visual Observations
M-V-B	50% Aqueous Solution of Hydrochloric Acid	Slight streak segregation. No shatter cracks. (see Figure 20).
H-C-B	50% Aqueous Solution of Hydrochloric Acid	Moderate to high amount of streak segregation. No shatter cracks. (see Figure 21).

TABLE 9A

MICROSCOPIC EXAMINATION

(PLANE TRANSVERSE TO THE DIRECTION OF ROLLING)

Specimen No.	Etchant	Magnification	Grain Size* Type of Crystal
M-V-B	2% Nital	100X	4-1/2 to 7 predominant 6 equiaxed pearlitic grains. (see Figure 22).
H-C-B	2% Nital	100X	3-1/2 to 6-1/2 predominant 5 equiaxed pearlitic grains. (see Figure 23).

TABLE 9B

MICROSCOPIC EXAMINATION

(PLANE LONGITUDINAL TO THE DIRECTION OF ROLLING)

Specimen No.	Etchant	Magnification	Cleanliness Ratings**
M-V-B	Unetched	100X	Sulfide Type (A) - Numerous No. 2 heavy series. Maximum No. 3 heavy series. Alumina Type (B) - None. Silicate Type (C) - Maximum No. 2 thin series. Oxide Type (D) - Maximum No. 2 thin series. Mostly No. 1 thin series (see Figure 24).
H-C-B	Unetched	100X	Sulfide Type (A) - No. 2 thin series maximum.
H-C-B	Unetched	100X	Alumina Type (B) - No. 3 thin series maximum. Silicate Type (C) - No. 1 thin series maximum. Oxide Type (D) - No. 1 thin series maximum. (see Figure 25).

* The average grain size was determined with the use of ASTM chart, Designation E-112, Plate I.

** Cleanliness determinations were made with the use of ASTM chart, Designation E-45, Plate I.

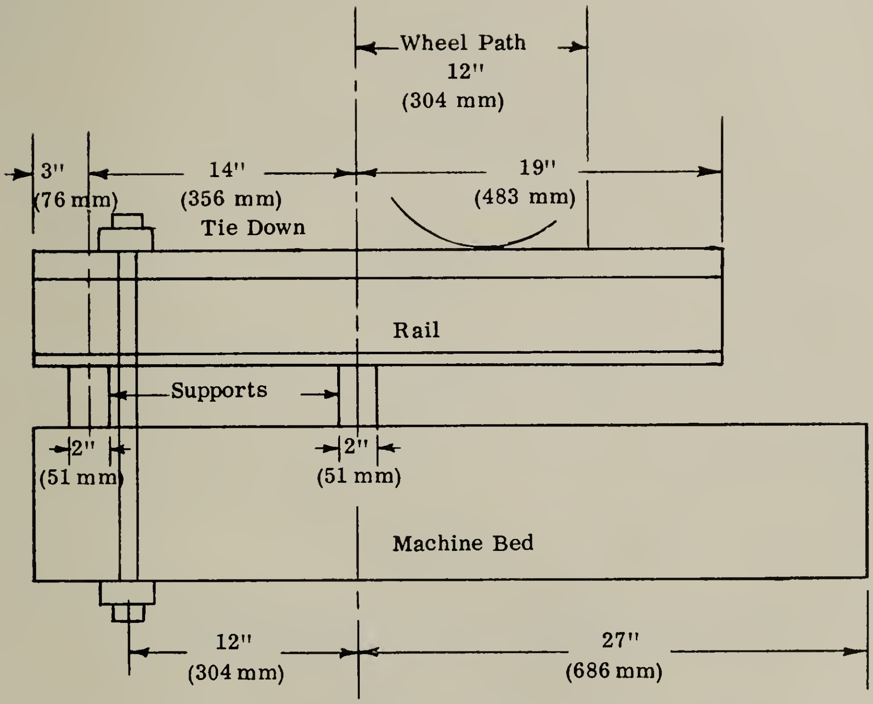
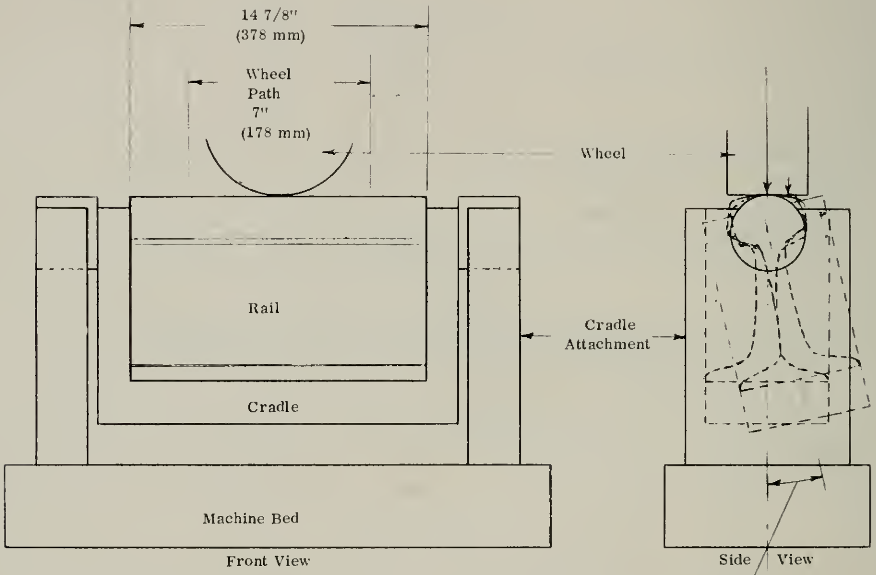
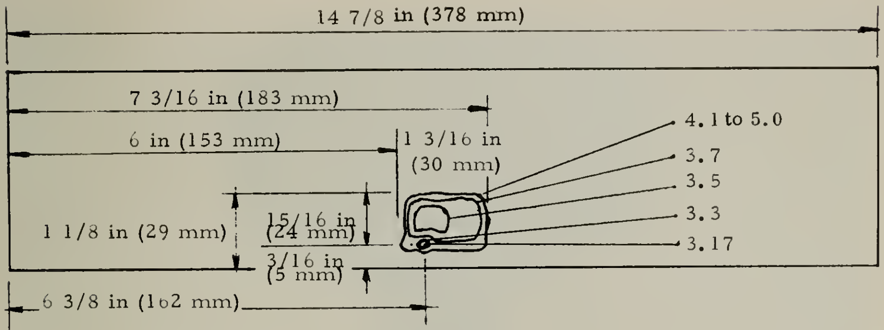


Fig. 1—Diagram showing the loading arrangement of the 12-inch-stroke rolling-load machine.



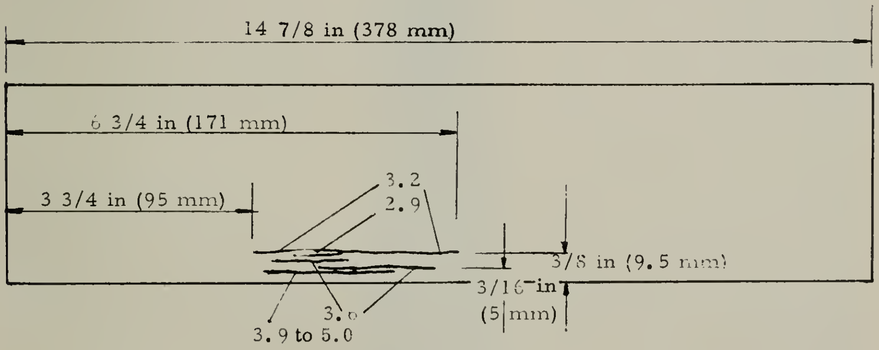
Rotates approximately 13° (0.23 rad) from vertical around gage corner

Fig. 2—Diagram showing the loading arrangement of the cradle-type rolling-load machine.



Top View

Rail Specimen H-C-C-1



Top View

Rail Specimen M-V-C-1

Note: Numbers represent millions of cycles.

Fig. 3—Propagation of shelling in rail specimen under rolling-load test.

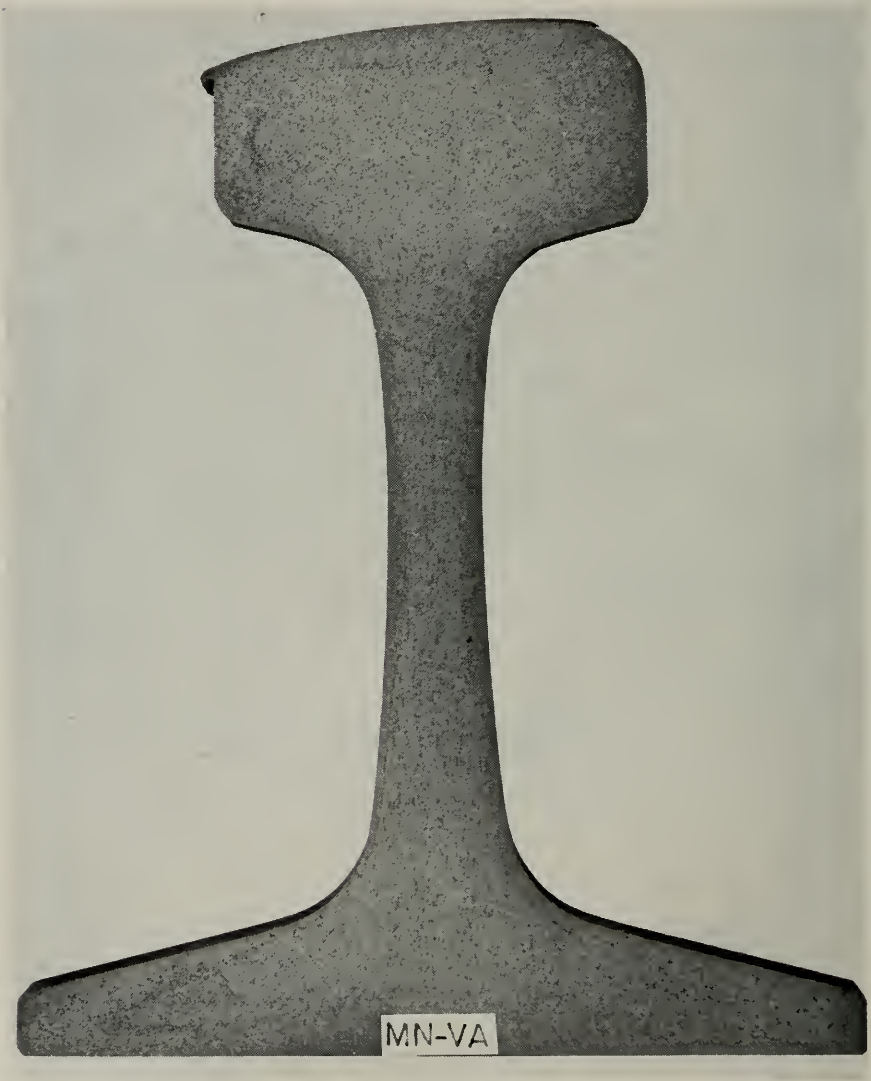


Fig. 4—Transverse section cut from specimen M-V-C3 after this specimen was subjected to 5,000,000 cycles in the cradle-type rolling-load machine.

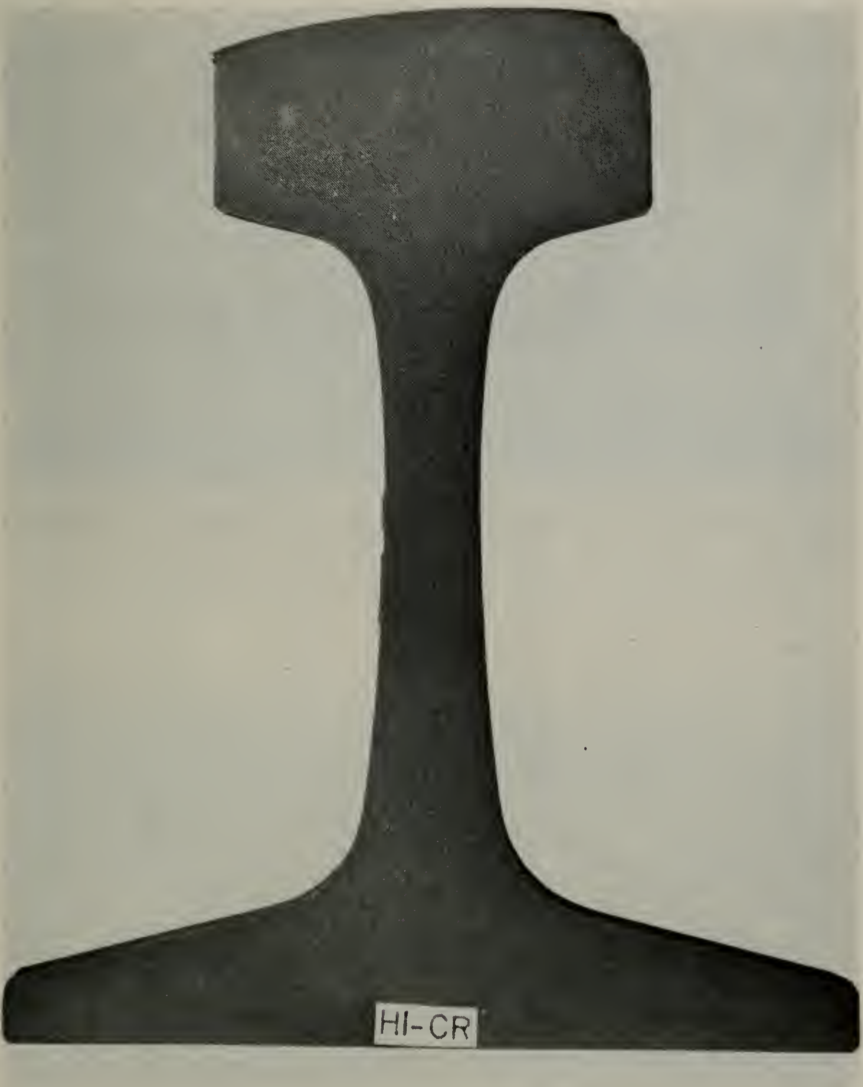


Fig. 5—Transverse section cut from specimen H-C-C3 after this specimen was subjected to 5,000,000 cycles in the cradle-type rolling-load machine.

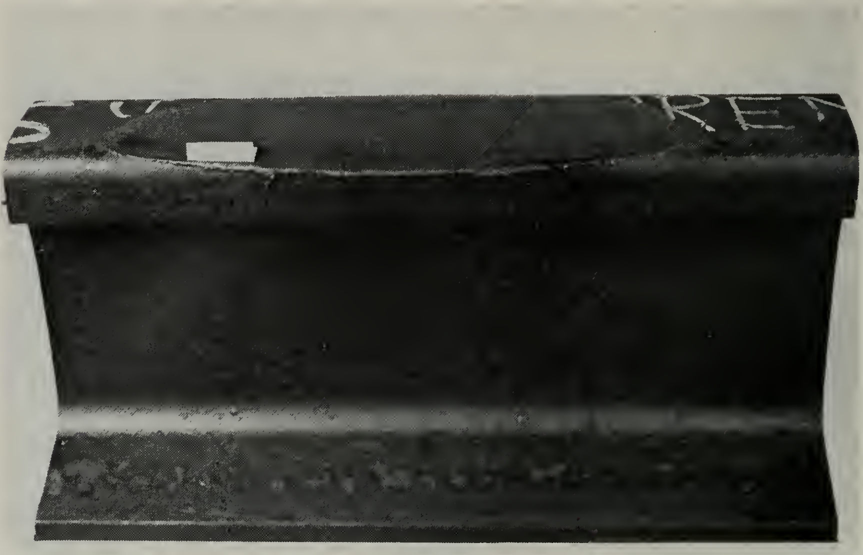


Fig. 6—Side view of specimen M-V-C3 after 5,000,000 cycles in the cradle-type rolling-load machine.

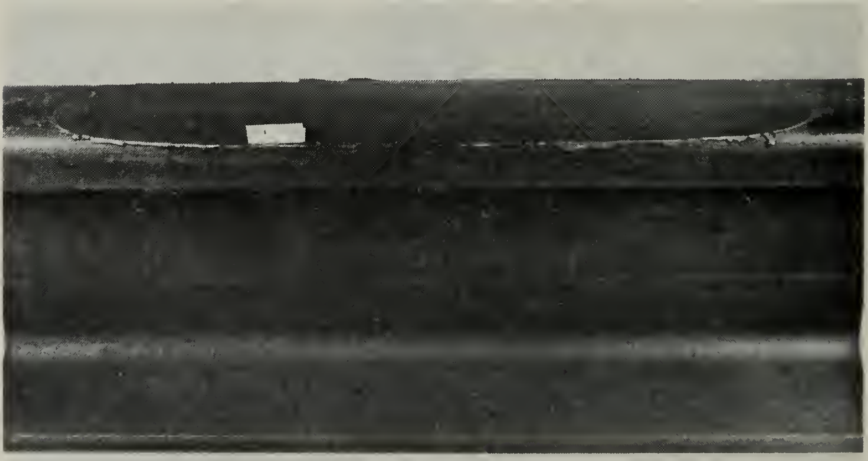


Fig. 7—Side view of specimen H-C-C3 after 5,000,000 cycles in the cradle-type rolling load machine.

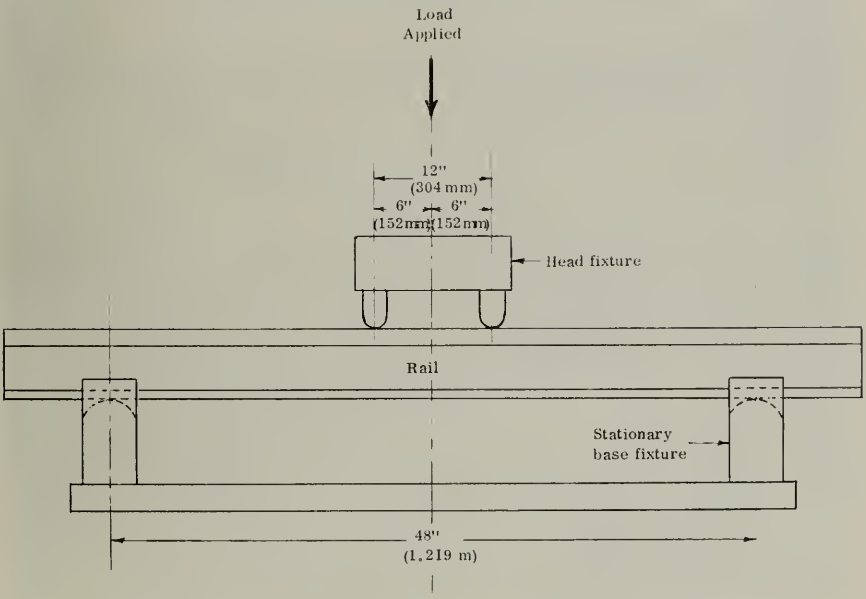


Fig. 8—Diagram showing the loading arrangement of the slow bend test.

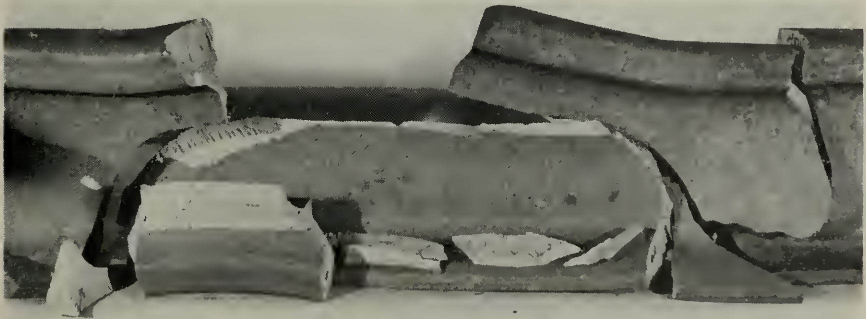


Fig. 9—Side view of specimen M-V-A (manganese-vanadium) showing the break resulting from slow bend testing.

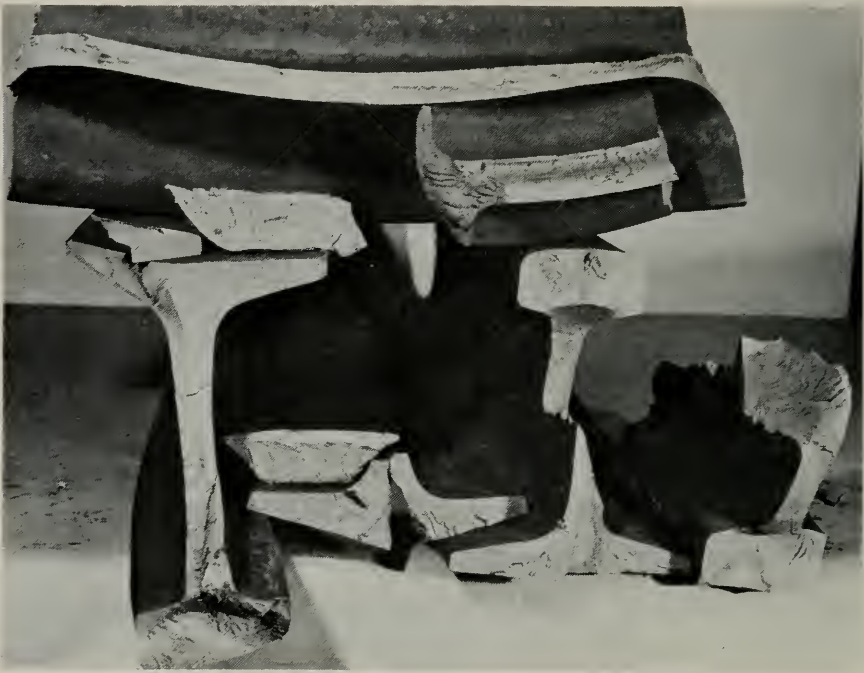


Fig. 10—Fractured faces of specimen M-V-A shown in Fig. 9.

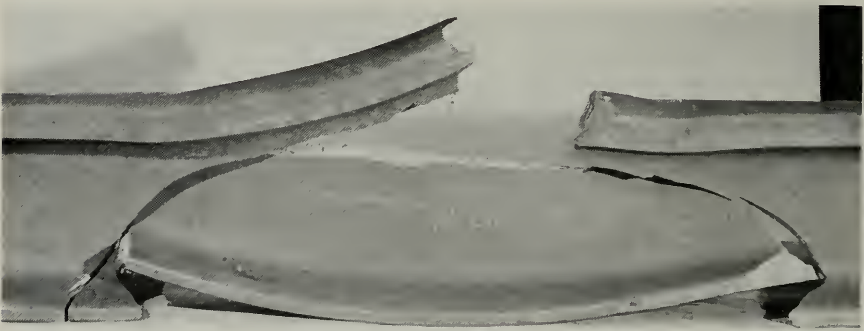


Fig. 11—Side view of specimen H-C-A (chromium) showing the break resulting from slow bend testing.

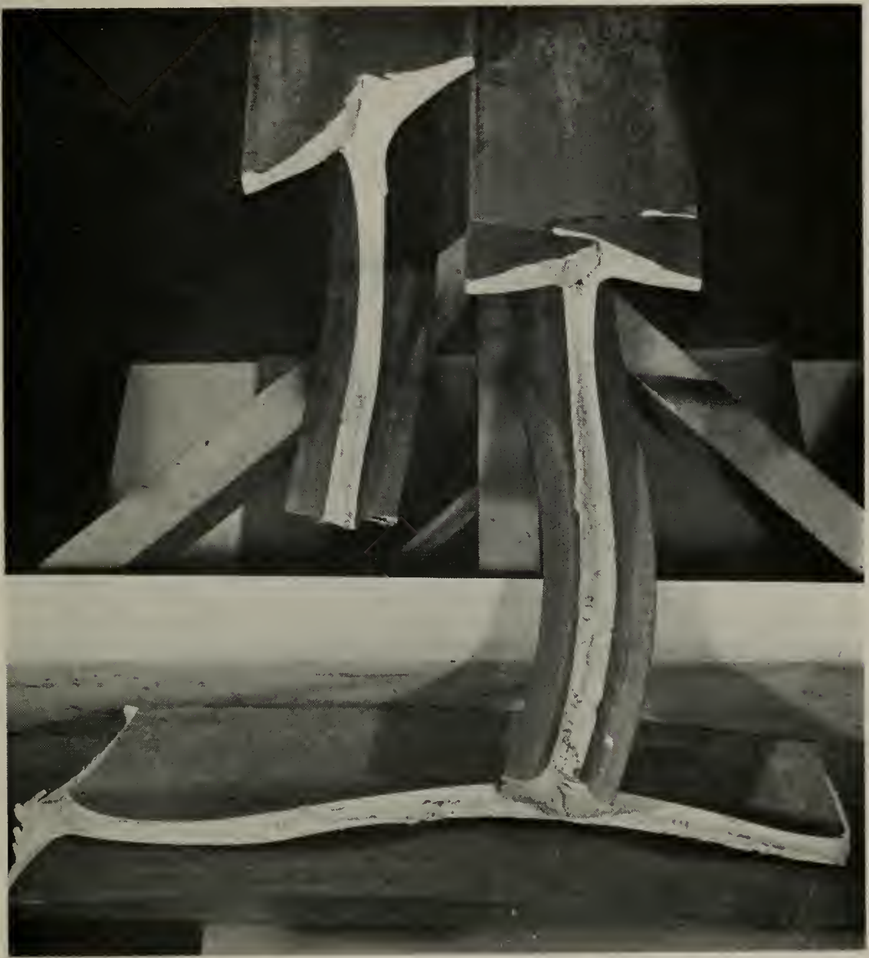


Fig. 12—Fractured faces of specimen H-C-A shown in Fig. 11.

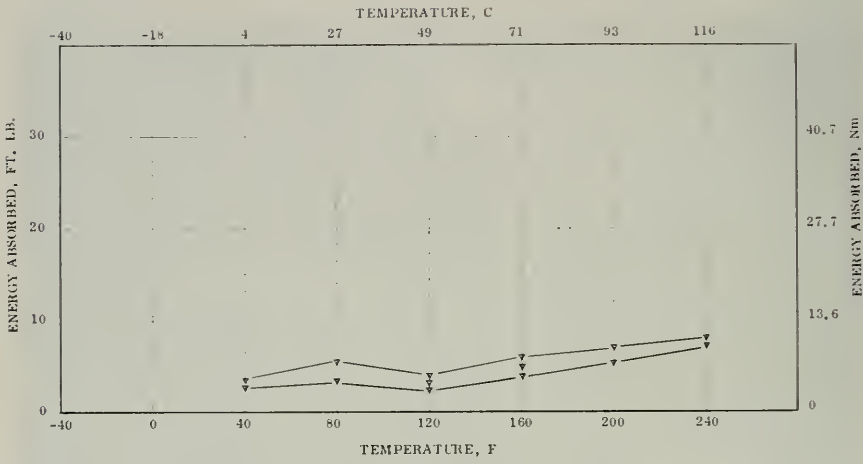


Fig. 13—Plot of charpy impact test results, manganese-vanadium rail steel.

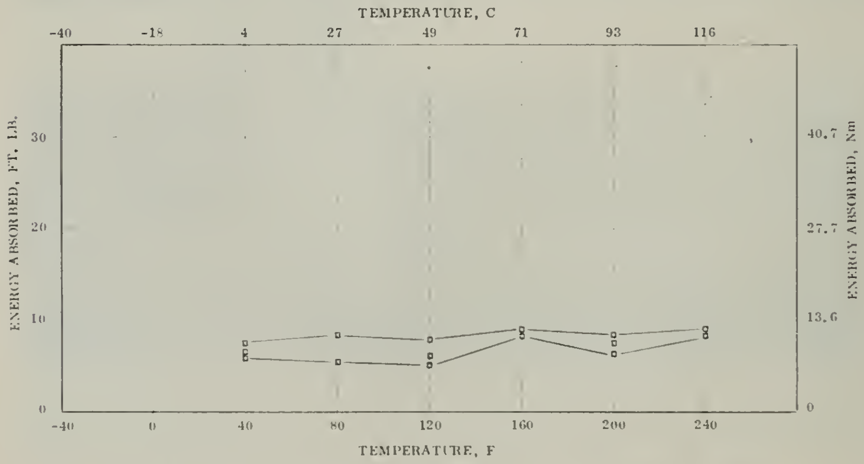


Fig. 14—Plot of charpy impact test results, chromium rail steel.

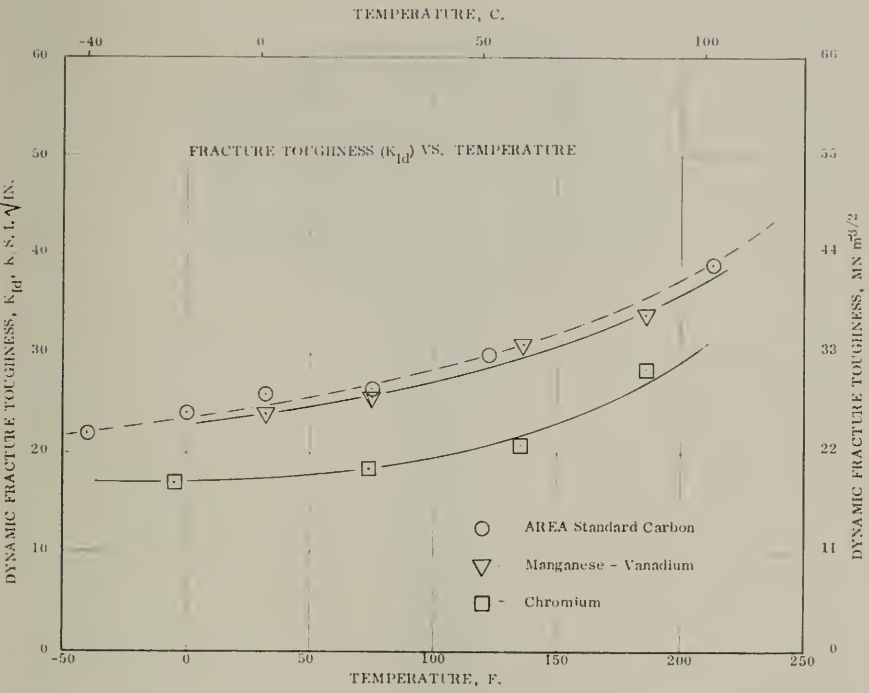

TEMPERATURE, C.
-40
0
50
100
60
50
40
30
20
10
0
66
55
44
33
22
11
0
FRACTURE TOUGHNESS (K_{Id}) VS. TEMPERATURE
DYNAMIC FRACTURE TOUGHNESS, K_{Id}, K.S.I.$\sqrt{IN.}$
DYNAMIC FRACTURE TOUGHNESS, MN $m^{3/2}$
○ AREA Standard Carbon
▽ Manganese - Vanadium
□ Chromium
-50
0
50
100
150
200
250
TEMPERATURE, F.

Fig. 15.

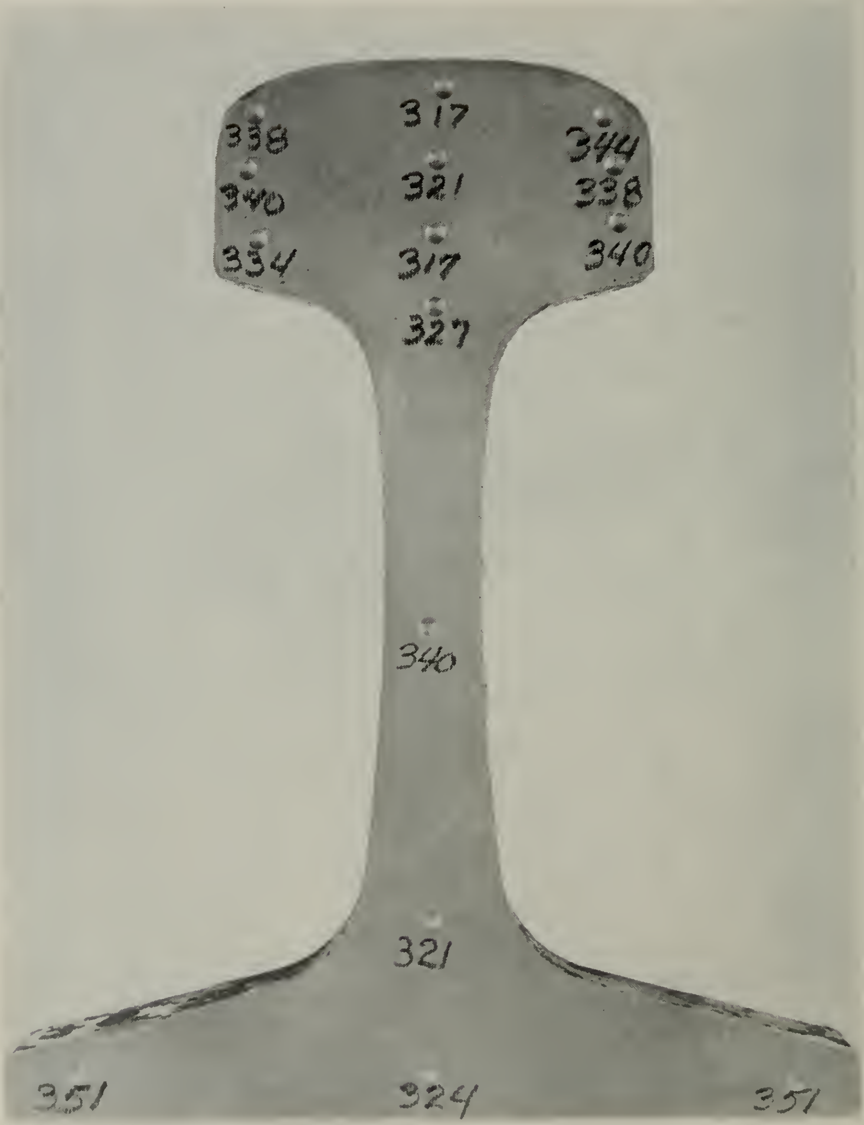


Fig. 16—Results of a hardness survey made on a transverse section cut from specimen M-V-B.

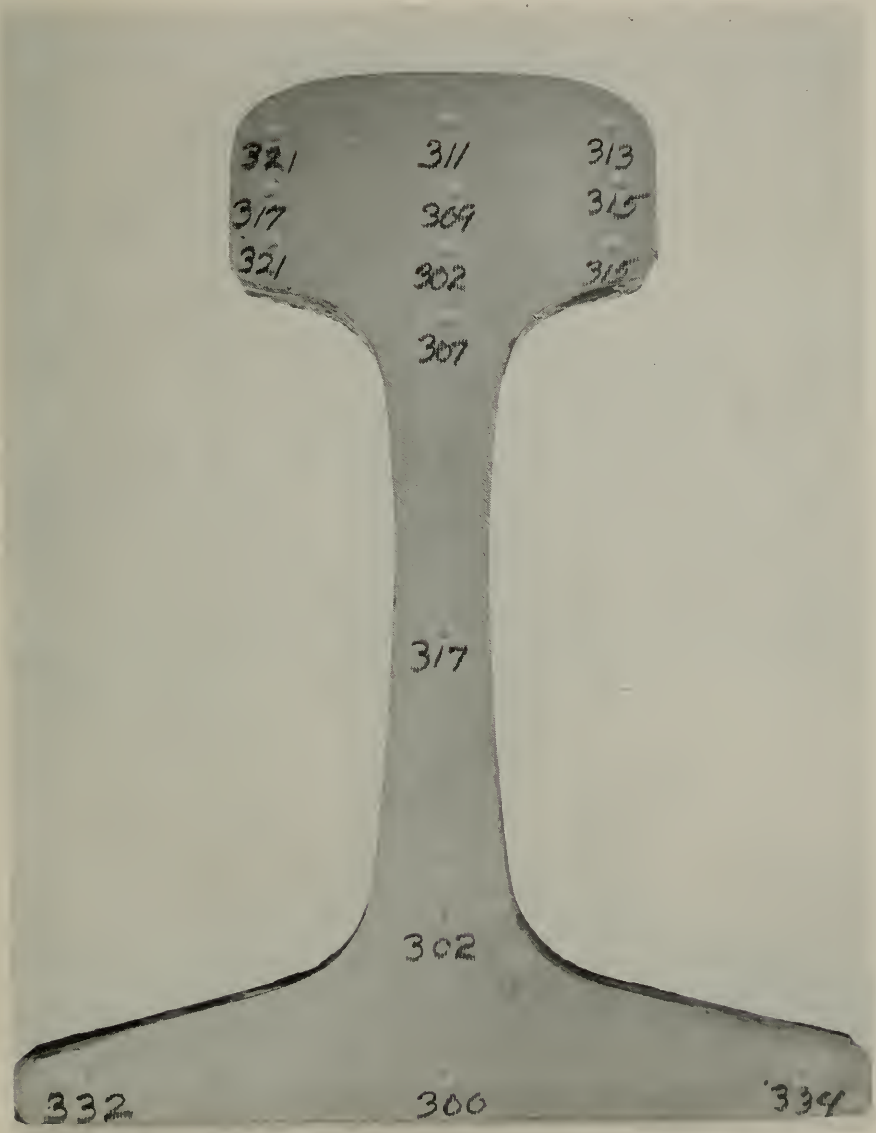


Fig. 17—Results of a hardness survey made on a transverse section cut from specimen H-C-B.

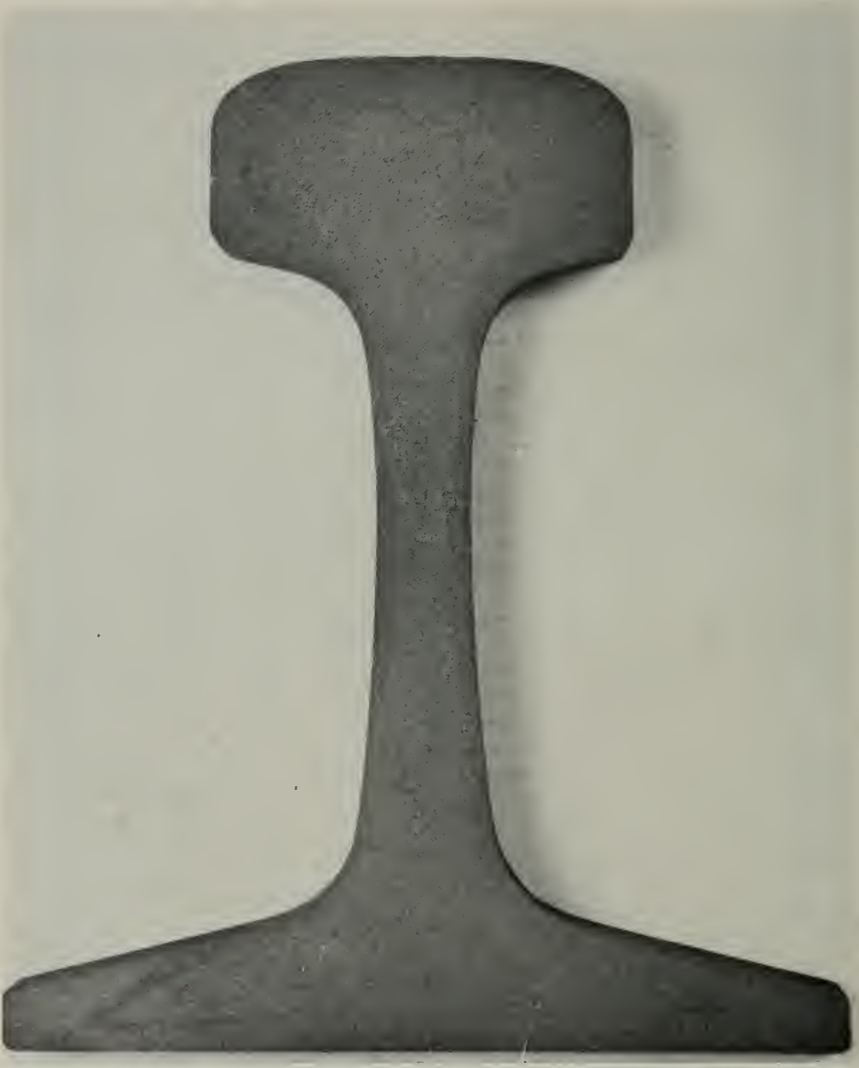


Fig. 18—Macroetched transverse section cut from specimen M-B-B. Etchant—hot 50 percent aqueous solution of hydrochloric acid.

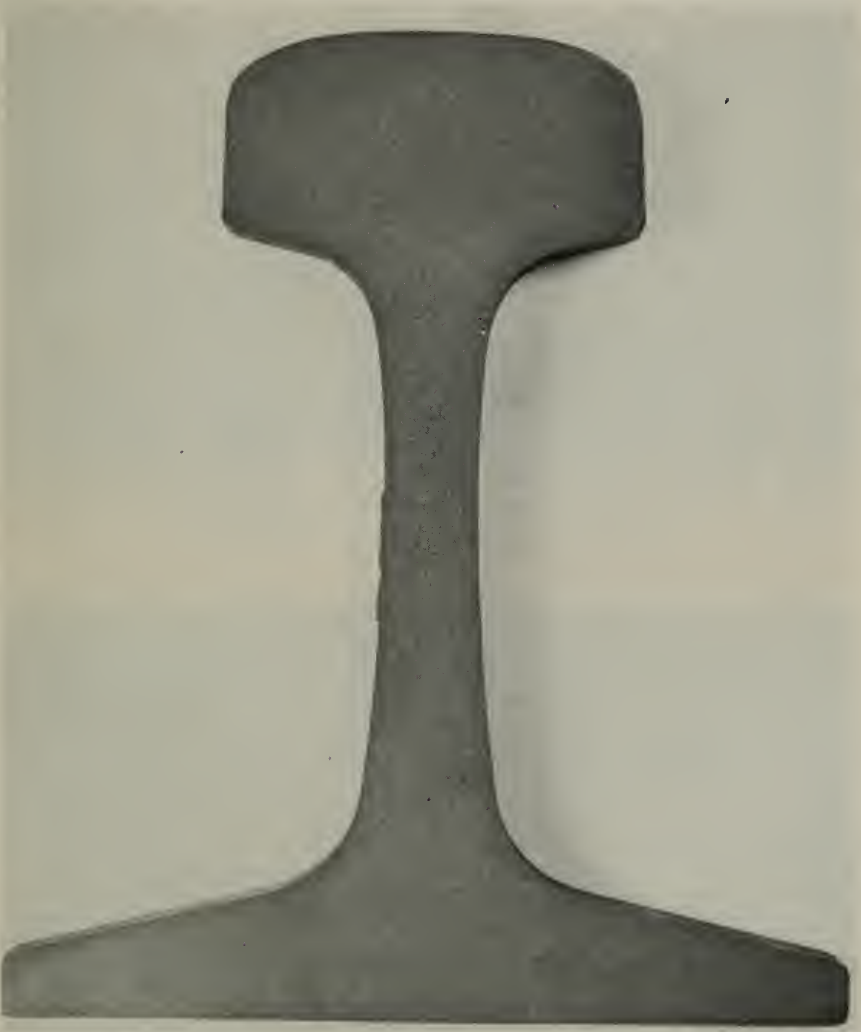


Fig. 19—Macroetched transverse section cut from specimen H-C-B. Etchant—hot 50 percent aqueous solution of hydrochloric acid.

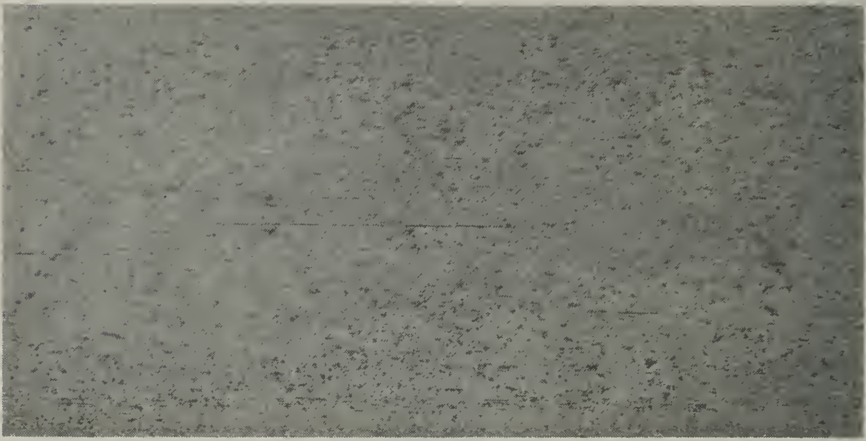


Fig. 20—Macroetched longitudinal section cut from specimen M-V-B. Etchant—hot 50 percent aqueous solution of hydrochloric acid.

Fig. 21—Macroetched longitudinal section cut from specimen H-C-B. Etchant—hot 50 percent aqueous solution of hydrochloric acid.

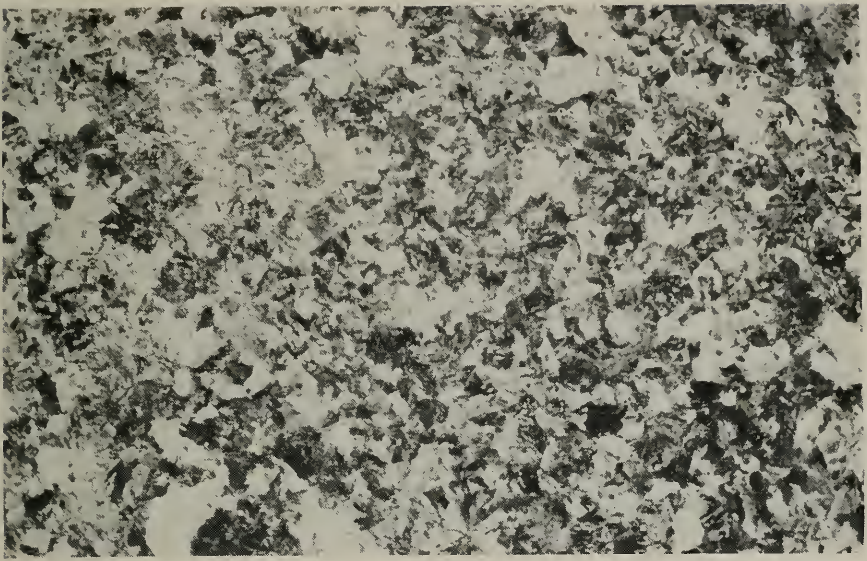


Fig. 22—Photomicrograph showing the grain structure in specimen M-V-B. Etchant—2 percent nital; magnification—100X.

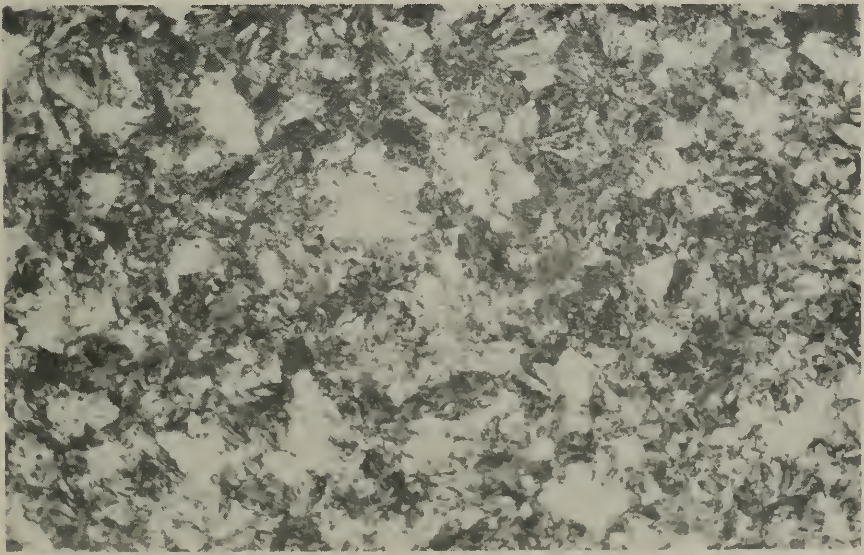


Fig. 23—Photomicrograph showing the grain structure in specimen H-C-B. Etchant—2 percent nital; magnification—100X.

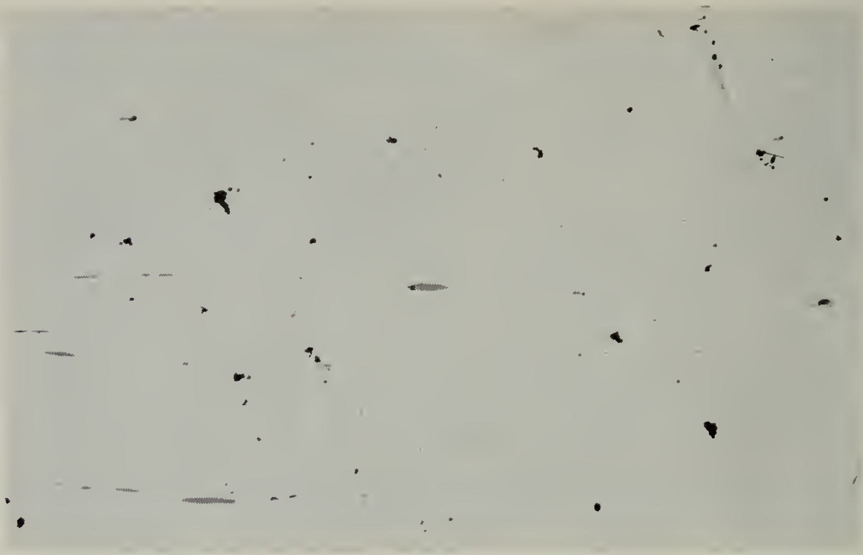


Fig. 24—Photomicrograph showing the steel cleanliness of specimen M-V-B. Etchant-unetched; magnification—100X.

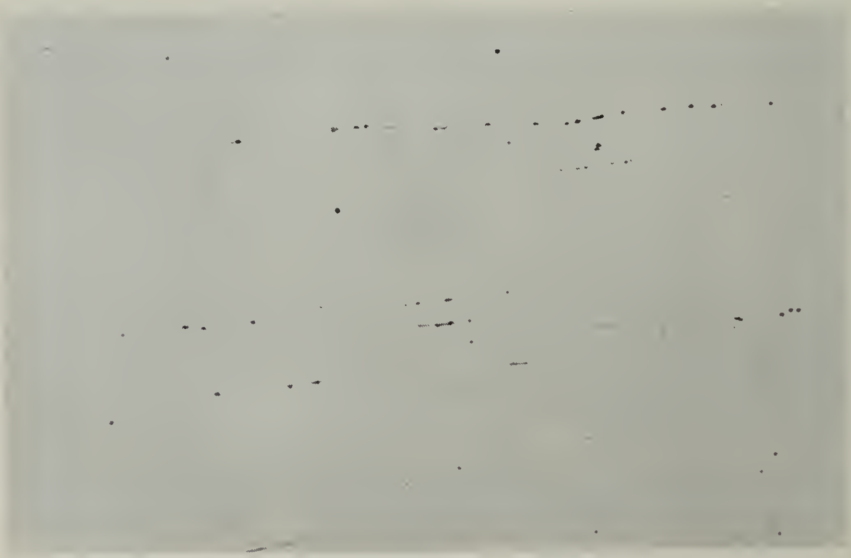


Fig. 25—Photomicrograph showing the steel cleanliness of specimen H-C-B. Etchant-unetched; magnification—100X.

PART 2

SUMMARY OF PERFORMANCE OF STANDARD-CARBON AND VARIOUS WEAR-RESISTANT RAILS IN TEST CURVES ON THE CHESSIE SYSTEM

K. W. SCHOENEBERG

Abstract

This report contains the summary of the first annual inspection of a service test installation of fully heat-treated, induction-head-hardened, intermediate-manganese and standard control-cooled rail on the Chessie System.

The field inspection is part of the cooperative effort on rail research of the American Railway Engineering Association, the American Iron and Steel Institute and the Association of American Railroads to observe and analyze those rails in curved track that display some potential for improvement in wear-resistance and retarding the onset of shelling.

Measurements were made and recorded of curvature, superelevation and gage, and general track conditions noted of four service test curves located near Oakland, Maryland. Rail head cross-section contours were taken and recorded of 80 test rails contained in these curves.

Introduction

As part of the programs on rail research, the AAR Research and Test Department is continuing its field study and analysis of those rails that continue in service which show some potential for improvement in curve wear resistance and ability to retard the onset of shelling. Rails that are heat-treated, have a variance in chemical composition from that of standard rail or which are unconventionally produced are part of this study.

The field inspections are carried out as a cooperative effort of the Rail Research and Development Subcommittee of AREA Committee 4—Rail, the AISI Technical Subcommittee on Rail and Accessories, the AAR Research and Test Department and the railroad on whose property the test rails are installed.

Through this and several other field service tests presently being progressed by these organizations, rail wear data as well as tonnage, track component, roadbed and environment data are being generated. The correlation of these data will result in the development of rail wear rates for various combinations of track and service conditions. A further correlation of these rail wear rates with other rail metallurgical and economic studies data can set forth, as an end product, criteria or recommendations establishing the appropriate selection of rail by section (weight) and kind (standard, alloy or heat-treated) to be used by the railroads at locations of high-wear or short calendar rail life.

Acknowledgement

Appreciation is hereby acknowledged of the invitation of J. T. Collinson, then general manager–chief engineer and now vice president–operations & maintenance, Chessie System, for AAR, AISI and AREA to participate with Chessie on the inspection and evaluation of their rail service test installation. Sincere appreciation

is expressed by those of AAR, AISI and AREA for the time and efforts rendered by Chessie personnel listed below in the preparation and conduct of this inspection.

Inspection of the rail in the four service test curves near Oakland was made on July 31, 1973. The following individuals were in the inspection party: A. L. Maynard, A. J. Kozak, C. L. Bialik, D. S. Young, and I. A. Reiner, Chessie System; W. H. Chidley, American Iron and Steel Institute; G. G. Knupp and J. H. Martens, Bethlehem Steel Corporation; D. L. Saxon, U. S. Steel Corporation; G. H. Way and K. W. Schoeneberg, AAR.

DESCRIPTION OF TEST RAILS

The Chessie System established the service test of heat-treated, alloy and standard rail on July 7, 10 and 11, 1972, when the rails were installed in four curves on its No. 2 or eastbound main track west of Oakland. A total of 80 rails consisting of 16 each of the five following types were used:

(1) 140 RE fully heat-treated—Bethlehem Steel Corp.
(2) 140 RE induction-head-hardened (Curvemaster)—U. S. Steel Corp.
(3) 140 RE intermediate-manganese—Bethlehem Steel Corp.
(4) 140 RE standard-carbon control-cooled—Bethlehem Steel Corp.
(5) 140 RE standard-carbon control-cooled—U. S. Steel Corp.

Four rails of each type were laid out for each of the four different curves, two on the high side and two on the low side of each curve. The rails were randomly welded together in 10 rail strings by the electric flash butt method. These continuously welded strings were then installed in the curves, one on the high side and one opposite on the low side of each of the four curves. The four test curves chosen for this test are of varying curvature as follows:

Curve No. 1, 5°—50′ (299.5 m radius)
Curve No. 2, 8°—28′ (206.5 m radius)
Curve No. 3, 4°—00′ (436.7 m radius)
Curve No. 4, 8°—08′ (214.9 m radius)

Figs. 1 through 4 show detailed information of location, curve layout and placement of the various types of rails in each of the four test curves.

140 RE Fully Heat-Treated Rails

The fully heat-treated rail was produced by the Bethlehem Steel Corporation at its Steelton, Pennsylvania, plant in May, 1972. The average ladle chemical analysis of the heats of steel, from which the rails in the curves were rolled, is shown in the following tabulation:

Heat Number	*Date Rolled*	*Constituents (Percent)* C	*Mn*	*P*	*S*	*Si*
CT08943	5–19–72	0.74	0.86	0.015	0.038	0.17
CT07952	5–19–72	0.73	0.83	0.012	0.046	0.15
CT19017	5–19–72	0.78	0.85	0.017	0.045	0.18

Each rail from these heats was subjected to a single surface hardness check which revealed a range from 341 to 388 BHN. Of the 16 test rails, one rail had a hardness of 341 BHN, 11 rails each had a hardness of 363 BHN and four rails each had a hardness of 388 BHN.

140 RE Induction-Head-Hardened (Curvemaster) Rails

The Curvemaster rail was produced by the United States Steel Corporation at its Gary, Indiana, plant in April and December 1970. The average ladle chemical analysis of the heats of steel from which the rails in the curves were rolled is shown in the following tabulation:

Heat	*Date*			*Constituents (Percent)*		
Number	*Rolled*	*C*	*Mn*	*P*	*S*	*Si*
DO5611	12–22–70	0.79	0.78	0.018	0.018	0.14
94L143	4–30–70	0.78	0.81	0.009	0.019	0.19
73L669	12–22–70	0.76	0.85	0.008	0.023	0.23
81L707	12–22–70	0.76	0.83	0.013	0.025	0.17
80L680	12–22–70	0.75	0.81	0.022	0.026	0.23

The range of single surface brinell hardness readings of heat treatment of the test rails, which came from the five heats, was from 341 BHN to 388 BHN.

140 RE Intermediate-Manganese Rails

The intermediate-manganese rail was produced by the Bethlehem Steel Corporation at its Steelton plant in May 1972. The average ladle chemical analysis of the one heat of steel from which these test rails were rolled, is shown in the following tabulation:

Heat	*Date*			*Constituents (Percent)*		
Number	*Rolled*	*C*	*Mn*	*P*	*S*	*Si*
1M19010	5–18–72	0.60	1.36	0.026	0.044	0.28

A single surface hardness check of each rail coming from this heat of steel revealed a range of from 269 BHN to 321 BHN with an average of 293 BHN.

140 RE Standard Control-Cooled Rail

The standard control-cooled rail used in the test curves was produced by both Bethlehem Steel Corporation and United States Steel Corporation. The rail produced by Bethlehem was rolled at its Lackawanna, New York, plant during May and June, 1972. The average ladle chemical analysis of the heats of steel from which the test rails were rolled is shown in the following tabulation:

Heat	*Date*			*Constituents (Percent)*		
Number	*Rolled*	*C*	*Mn*	*P*	*S*	*Si*
181332	6–11–72	0.79	0.94	0.010	0.020	0.16
181107	5– 9–72	0.76	0.85	0.020	0.020	0.15
181110	5– 9–72	0.76	0.86	0.020	0.020	0.13
180991	5– 1–72	0.79	0.84	0.030	0.020	0.15

The rail produced by United States Steel was rolled at its Gary plant in December 1969 and January 1970. The average ladle chemical analysis of the heats of steel from which the test rails were rolled is shown in the following tabulation:

Heat	*Date*			*Constituents (Percent)*		
Number	*Rolled*	*C*	*Mn*	*P*	*S*	*Si*
59R647	12–29–69	0.74	0.81	0.026	0.023	0.17
85R812	12–29–69	0.76	0.92	0.010	0.026	0.17
71R078	12–29–69	0.76	0.76	0.010	0.022	0.18
63M022	1–18–70	0.76	0.77	0.008	0.029	0.17

The average hardness for standard control cooled rail, as established by many tests in past years, is in the range of 250 to 255 BHN and these test rails are assumed to come in that range although no hardness check was made at the mill or in the field.

CONDUCT OF THE INSPECTION

The inspection party examined all test rails in each of the four test curves, noting the condition of each rail as well as noting line and level of the track and conditions of the other track components. Rail head cross-section contours were taken at approximately the midpoint of each of the 80 test rails. The wear pattern of each is shown in Figs. 5 through 24. The gage of the track was measured and recorded at the locations where the rail head contours were taken. These are also shown in Figs. 5 through 24.

Stringlining measurements were made to check the degree of curvature of each curve, particularly in the body of the curves where the test rails were located, as a means of verifying the original degree of curvature and a check for any gross misalignment. Each curve was generally in good alignment and in conformance with the curvature as shown in Figs. 1 through 4 and 5 through 24.

Superelevation measurements were also made throughout each curve and these measurements revealed good consistency to the original superelevation placed in each curve. No gross deviations were found to those superelevations for each curve as noted in Figs. 1 through 4 and 5 through 24.

The four curves and the track through this location appeared to be well maintained and in good condition. Drainage of the roadbed and ballast section was good. The ballast was of crushed stone, well graded from 1¼ in (31.8 mm) size to smaller material with a depth of 12 in (304.8 mm) beneath the ties. The 7-in (177.8-mm) x 9-in (228.6-mm) hardwood treated ties were generally in good condition and their spacing center to center was 21¼ in (539.75 mm).

Double-shoulder tie plates, 8 in (203.2 mm) x 14 in (355.6 mm), support the rail with 3 spikes per plate being used. The continuous welded rail is anchored with 22 "unit" rail anchors per 39 ft (11.887 m) rail length, with a pattern of every other tie being box-anchored.

Rail lubricators are used in this territory of the railroad and thus a generally heavy to moderate amount of lubricant was noted on the gage side of the rail head throughout the test curves.

The gradient of the track through the test curves ranged from level to 1.15 percent (11.5 mm/m) descending eastward in the direction of travel of the predominantly mixed (manifest freight and unit coal) trains.

During the one full year that the test rails have been in service, tonnage over this territory of the railroad has been 14.6 million gross tons.

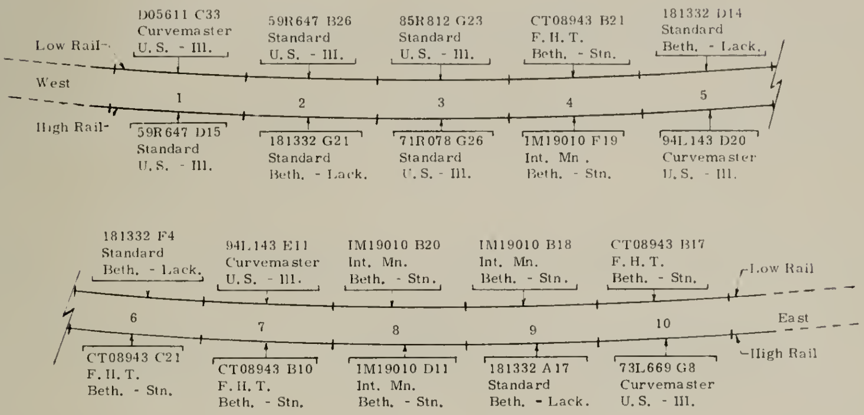
CONCLUSIONS

Rail head wear is minimal at this juncture of one year's service and comparatively low tonnage. Therefore, any comments or conclusions as to the relative merits of the five types of rail under comparison would be premature at this time.

ANSI-SI CONVERSION TABLE
(Taken From ASTM E 380)

To Convert From	*To*	*Multiply By*
Inch (in)	Metre (m)	2.540 000 E—02
Foot (ft)	Metre (m)	3.048 000 E—01

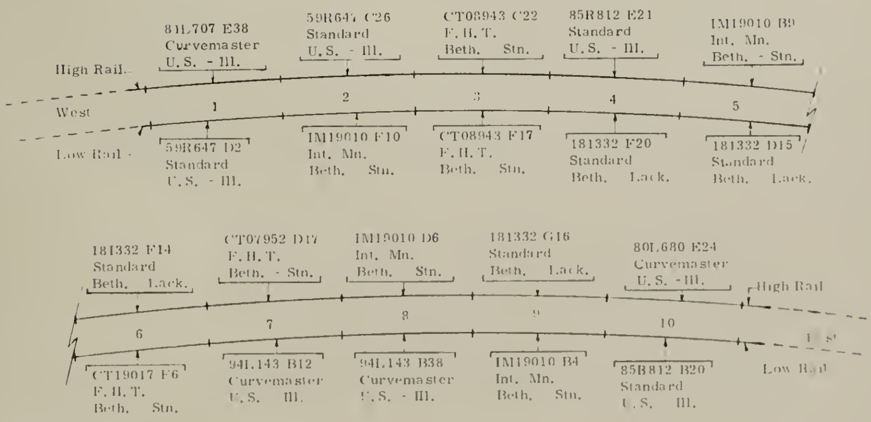
CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO.
5°-50' CURVE (299.5 m RADIUS)— 4-1/2 IN. SUPERELEVATION (114.3 mm)
MILE POST 233.1

FIGURE 1

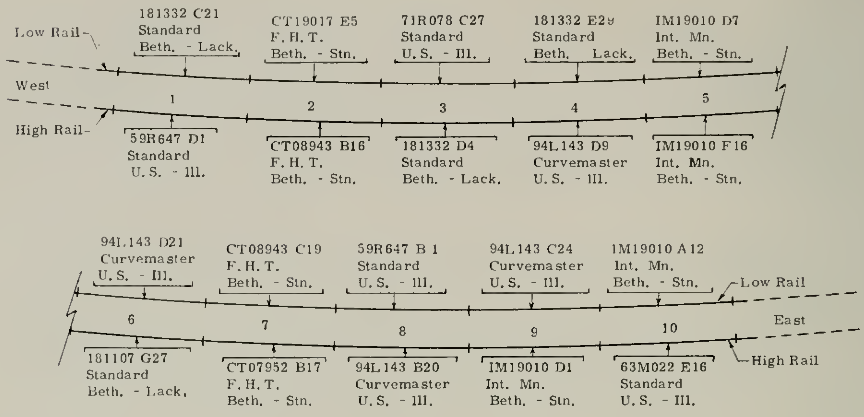
CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 2
8°-28' CURVE (206.5 m RADIUS) — 5 IN. SUPERELEVATION (127.0 mm)
MILE POST 233.2

FIGURE 2

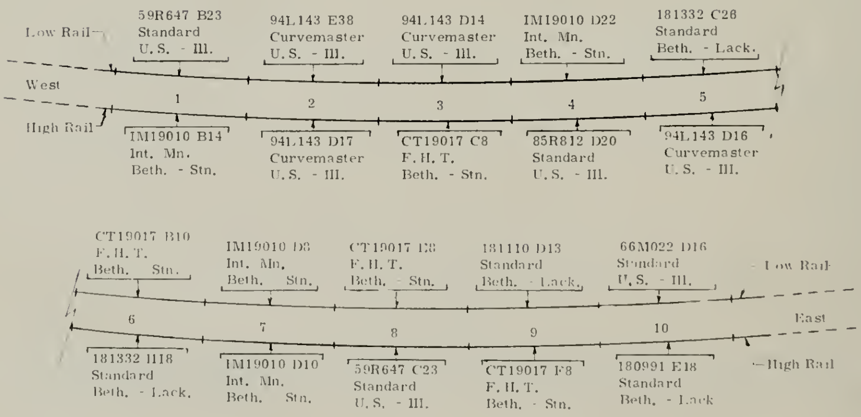
CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 3
4°-00' CURVE (436.6 m RADIUS) — 2-1/2 IN. SUPERELEVATION (63.5 mm)
MILE POST 234.0

FIGURE 3

CHESSIE SYSTEM RAIL TEST
NEAR OAKLAND, MARYLAND



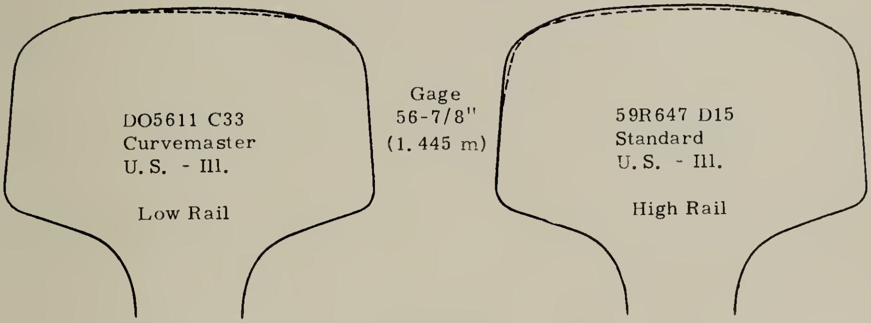
LAYOUT OF 140 LB. RE TEST RAILS - CURVE NO. 4
8°-08' CURVE (214.9 m RADIUS)— 5 IN. SUPERELEVATION (127.0 mm)
MILE POST 235

FIGURE 4

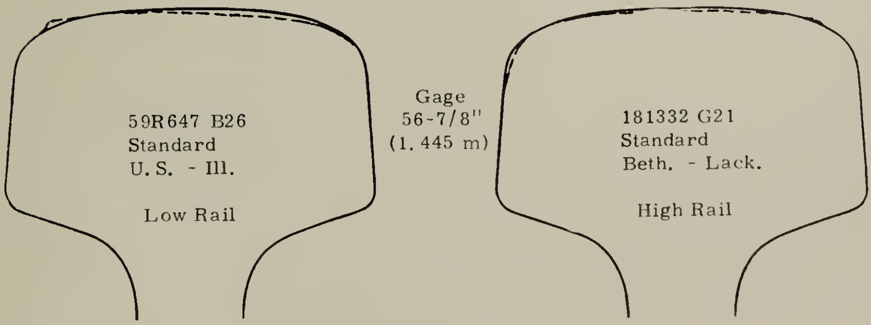
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1
5°-50' CURVE (299.5 m RADIUS) — SUPERELEVATION 4-1/2 IN. (114.3 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 1



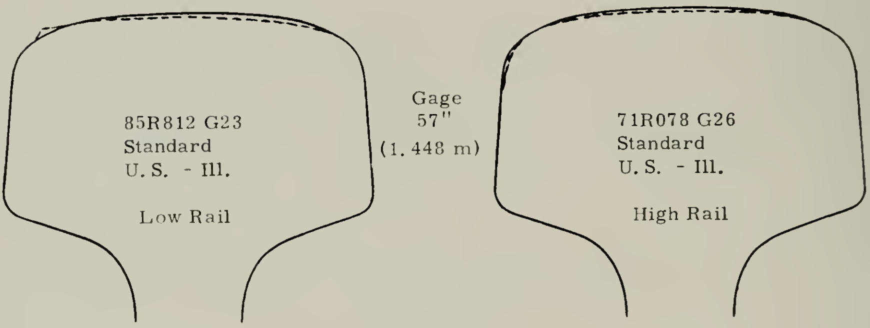
Location 2

FIGURE 5

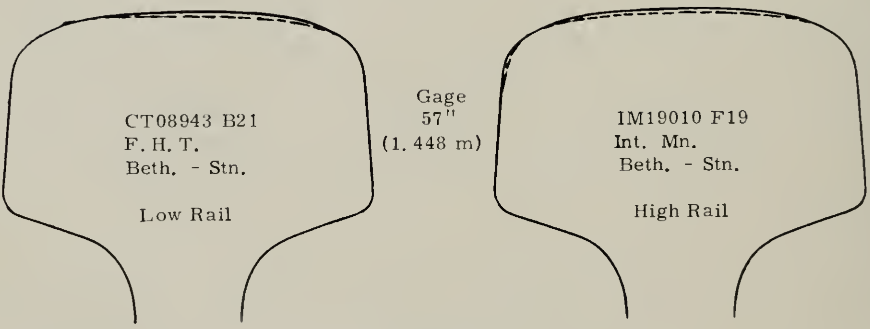
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1
5°-50' CURVE (299.5 m RADIUS)- SUPERELEVATION 4-1/2 IN. (114.3 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 3



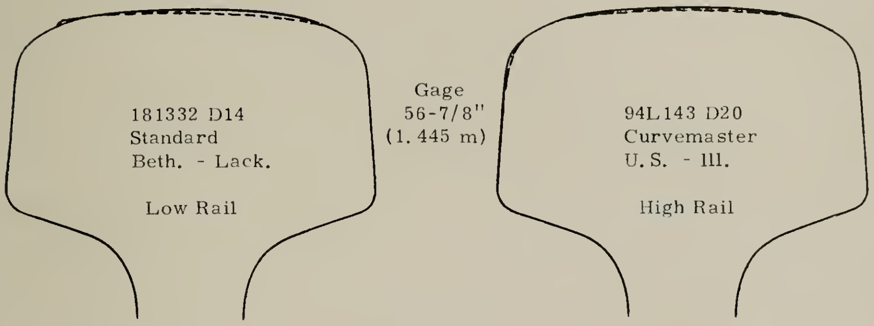
Location 4

FIGURE 6

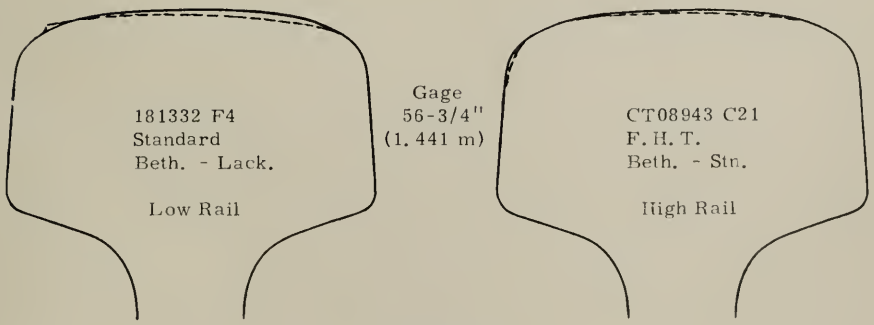
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233. 1
5°-50' CURVE (299. 5 m RADIUS)-SUPERELEVATION 4-1/2 IN. (114. 3 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 5



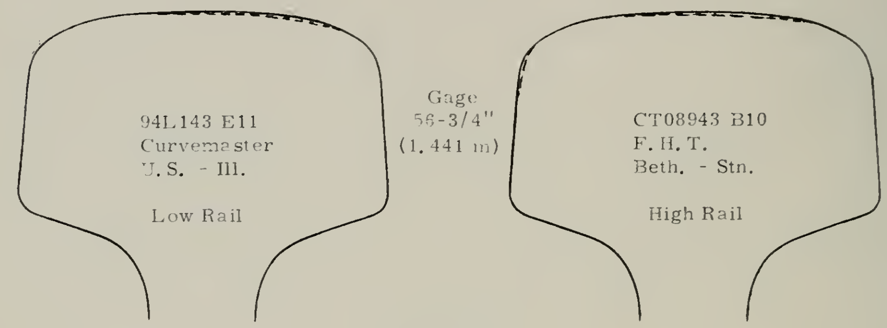
Location 6

FIGURE 7

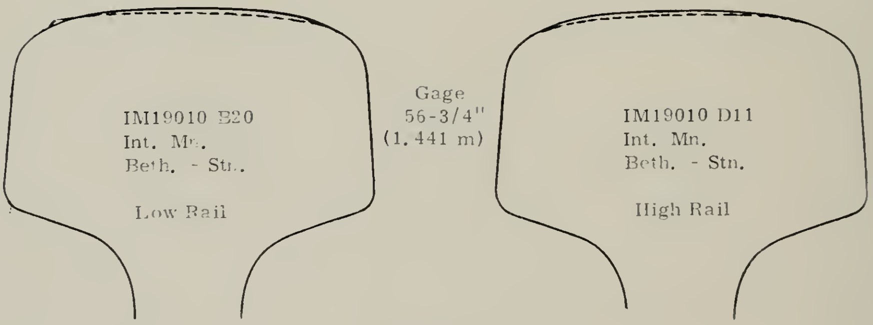
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1
5°-50' CURVE (299.5 m RADIUS)-SUPERELEVATION 4-1/2 IN. (114.3 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 7

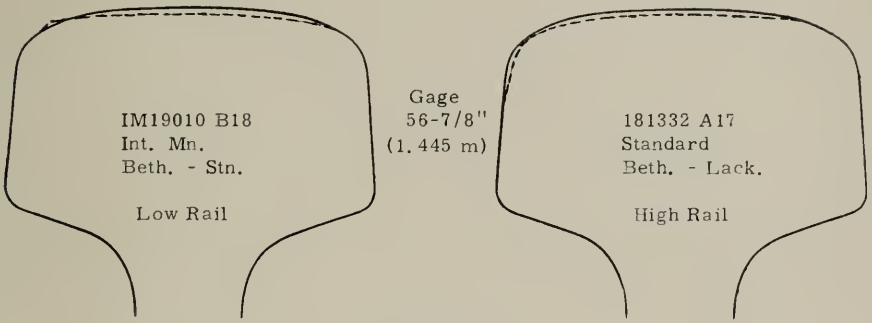


Location 8

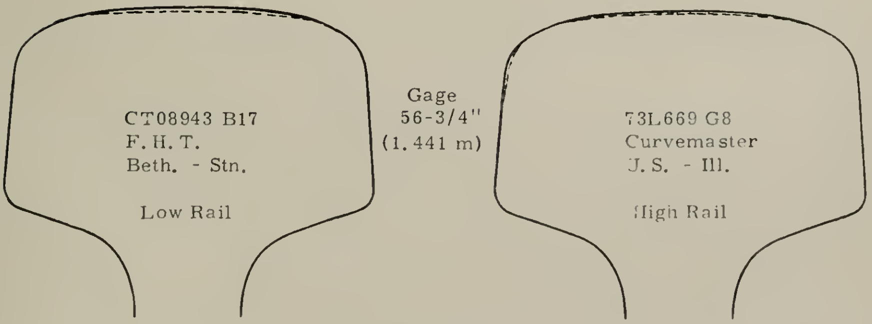
FIGURE 8

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 1 - MILE POST 233.1
5°-50' CURVE (299.5 m RADIUS)-SUPERELEVATION 4-1/2 IN. (114.3 mm)

INSTALLED: July 1972 INSPECTED: July 31, 1973



Location 9

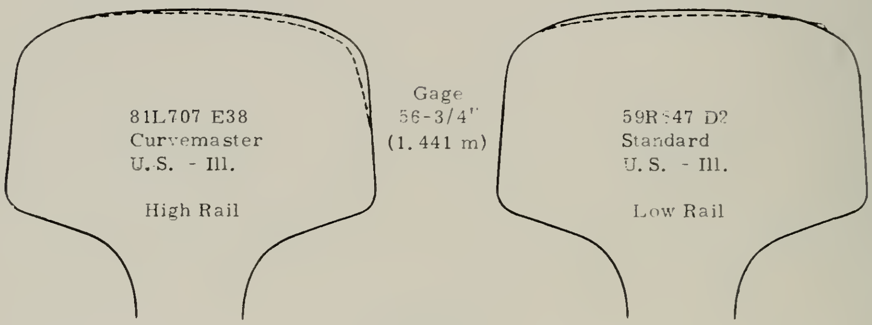


Location 10

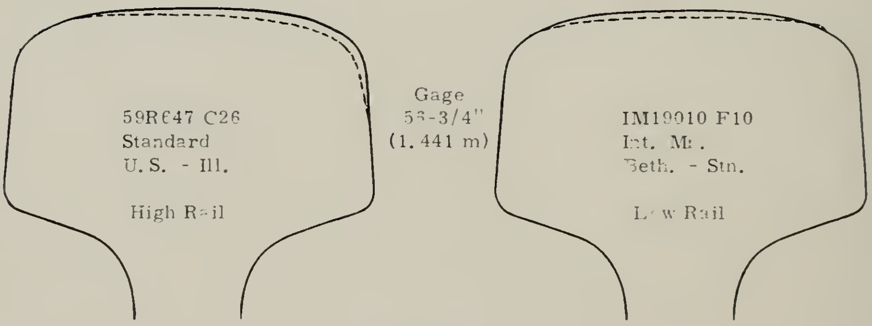
FIGURE 9

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2
8°-28' CURVE (206.5 m RADIUS) — SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972 INSPECTED: July 31, 1973



Location 1



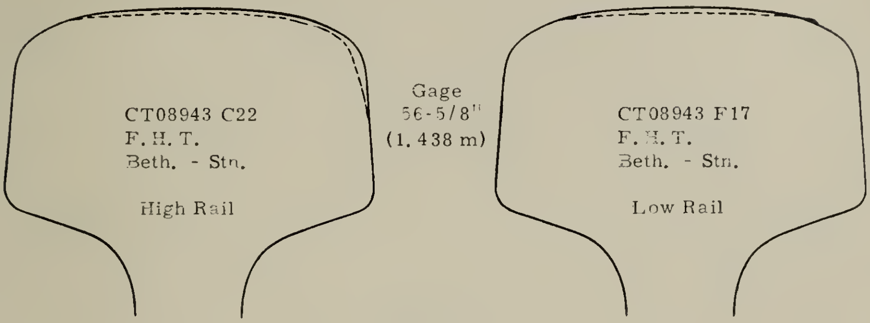
Location 2

FIGURE 10

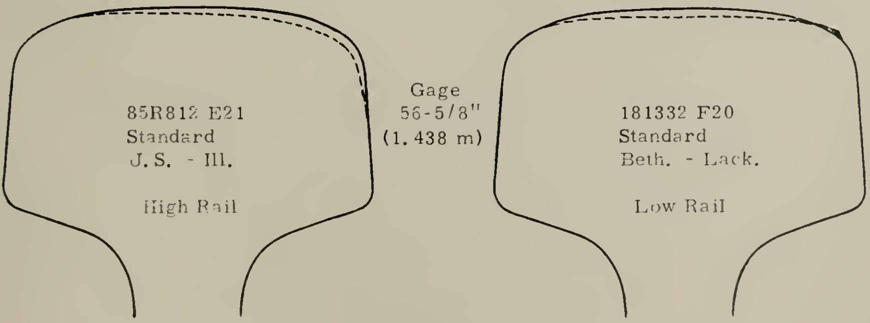
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2
8°-28' CURVE (206.5 m RADIUS) - SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 3

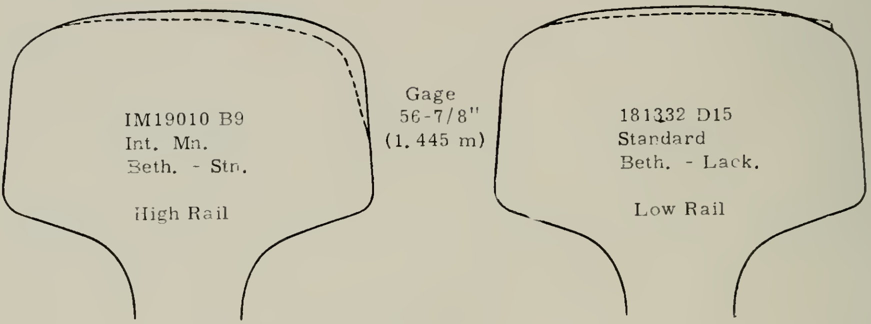


Location 4

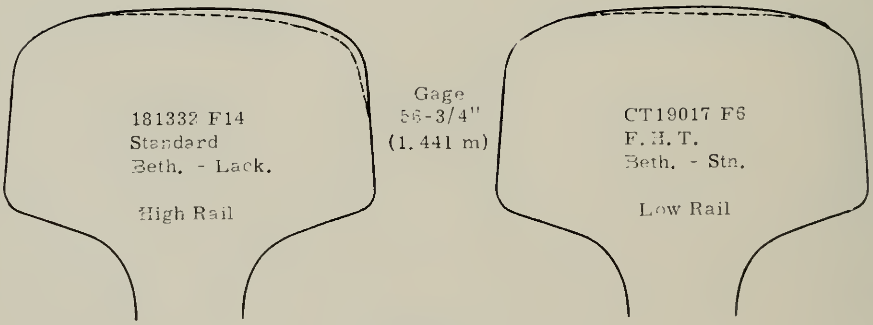
FIGURE 11

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2
8°-28' CURVE (206.5 m RADIUS) — SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972 INSPECTED: July 31, 1973



Location 5



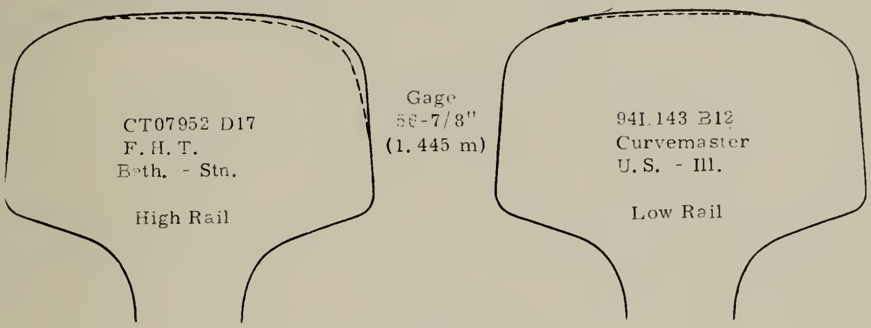
Location 6

FIGURE 12

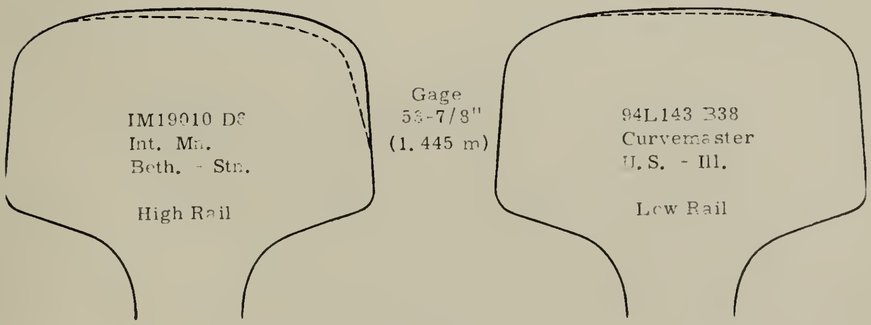
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2
8°-28' CURVE (206.5 m RADIUS) — SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 7



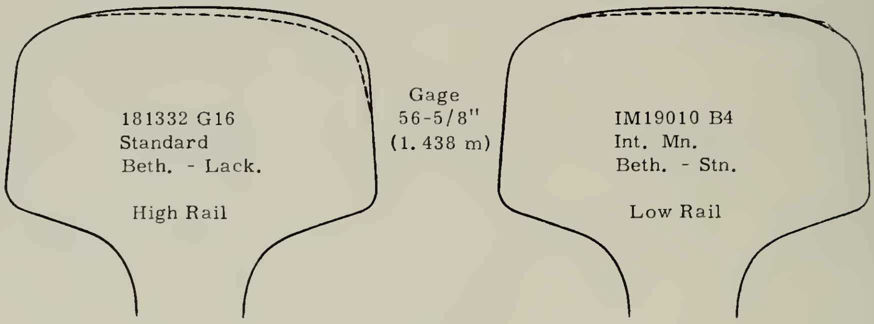
Location 8

FIGURE 13

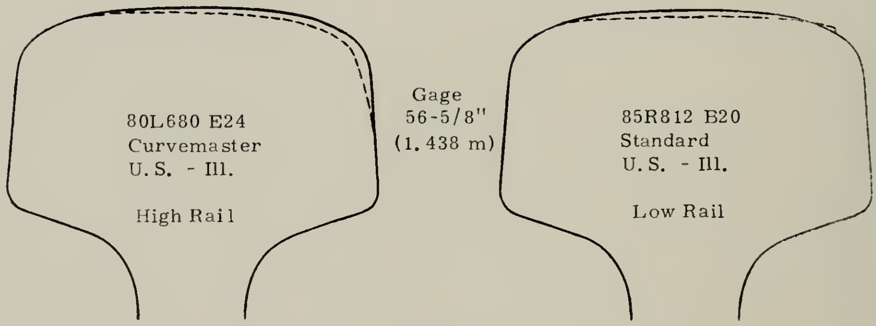
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 2 - MILE POST 233.2
8°-28' CURVE (206.5 m RADIUS) – SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 9

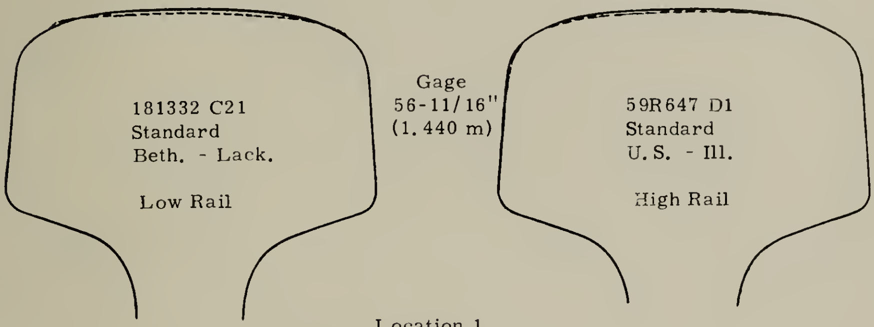


Location 10

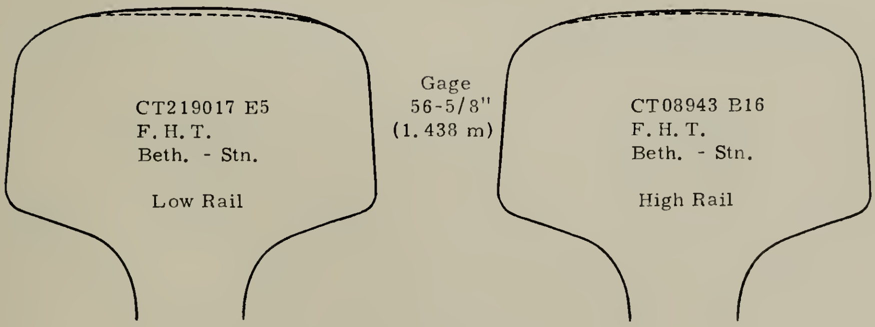
FIGURE 14

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0
4°-00' CURVE (436.6 m RADIUS)-SUPERELEVATION 2-1/2 IN. (63.5 mm)

INSTALLED: July 1972 INSPECTED: July 31, 1973



Location 1



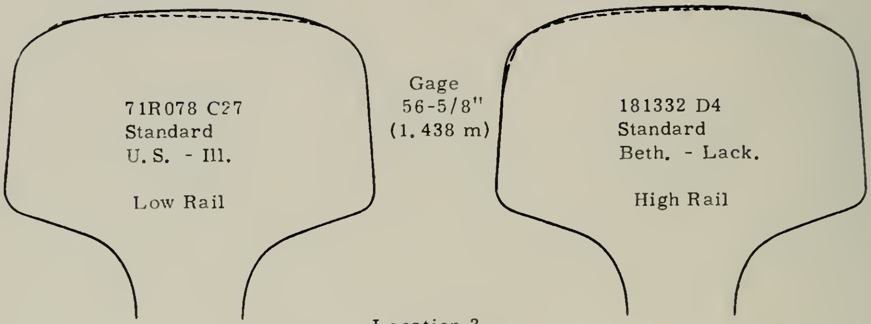
Location 2

FIGURE 15

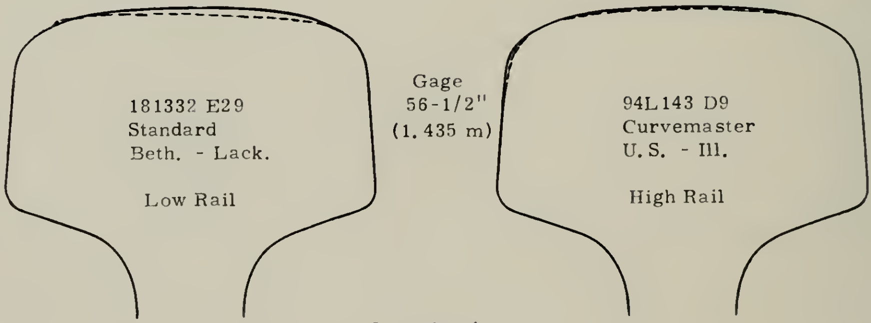
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0
4°-00' CURVE (436.6 m RADIUS) - SUPERELEVATION 2-1/2 IN. (63.5 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 3



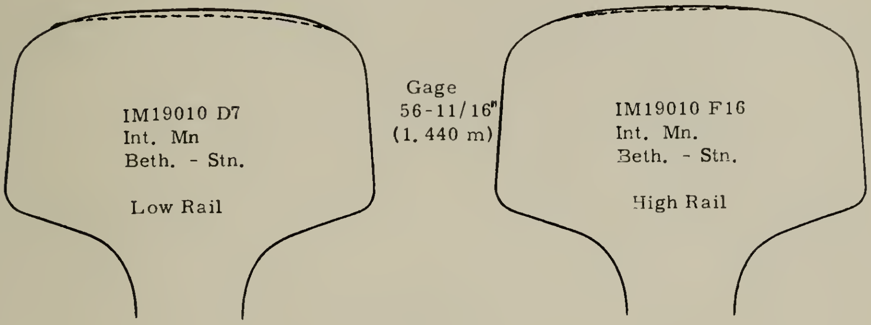
Location 4

FIGURE 16

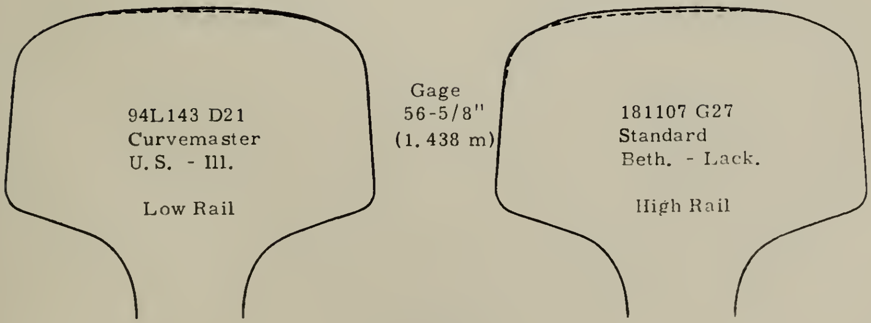
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0
4°-00' CURVE (436.6 m RADIUS) - SUPERELEVATION 2-1/2 IN. (63.5 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 5



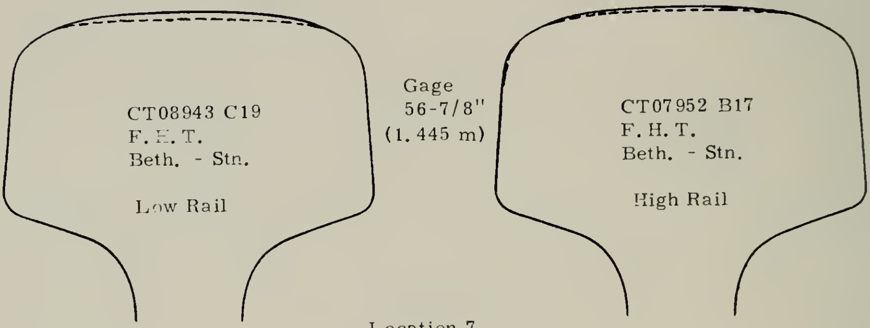
Location 6

FIGURE 17

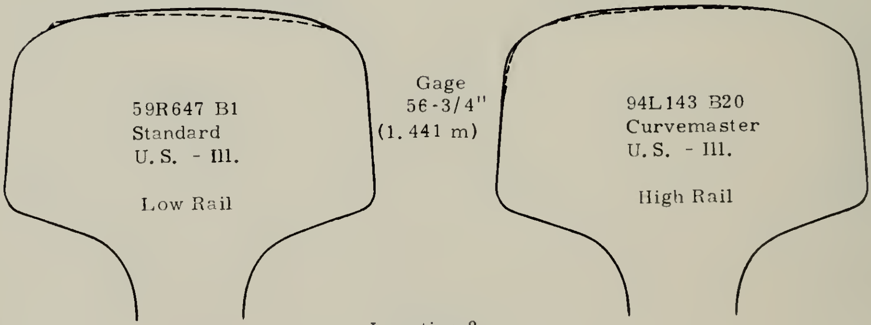
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0
4°-00' CURVE (436.6 m RADIUS) - SUPERELEVATION 2-1/2 IN. (63.5 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 7



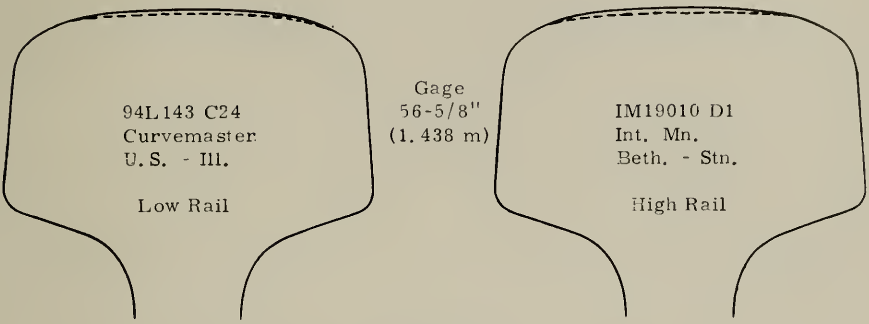
Location 8

FIGURE 18

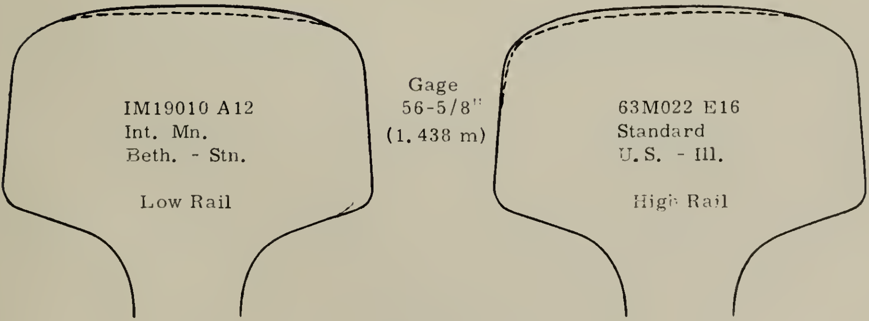
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 3 - MILE POST 234.0
4°-00' CURVE (436.6 m RADIUS) – SUPERELEVATION 2-1/2 IN. (63.5 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 9



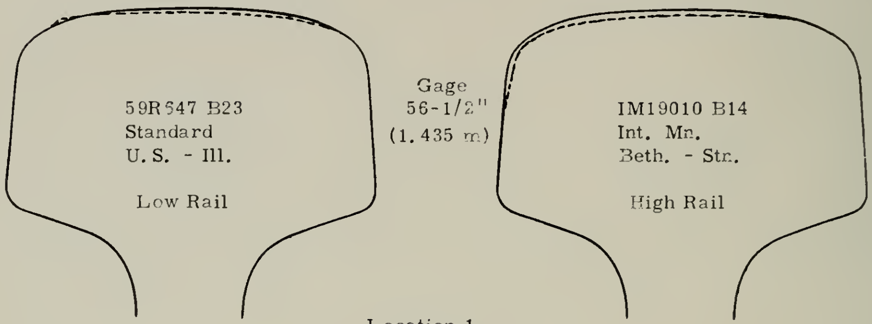
Location 10

FIGURE 19

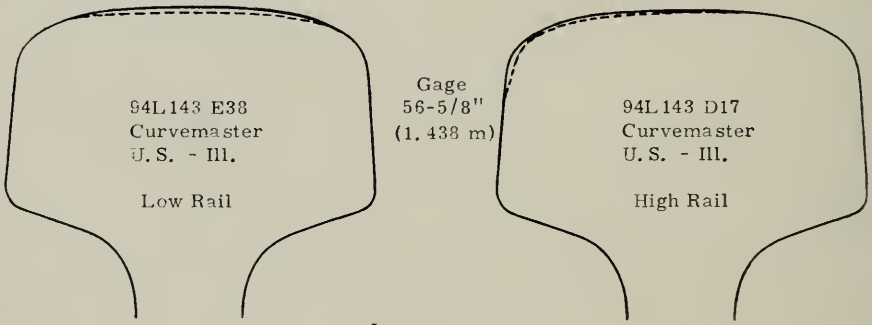
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0
8°-08' CURVE (214.9 m RADIUS)-SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 1

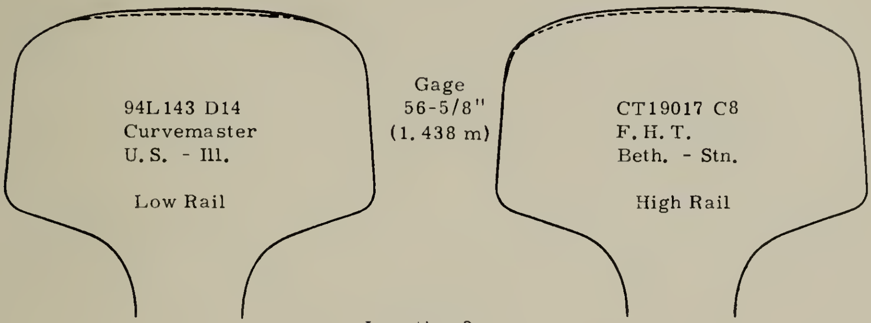


Location 2

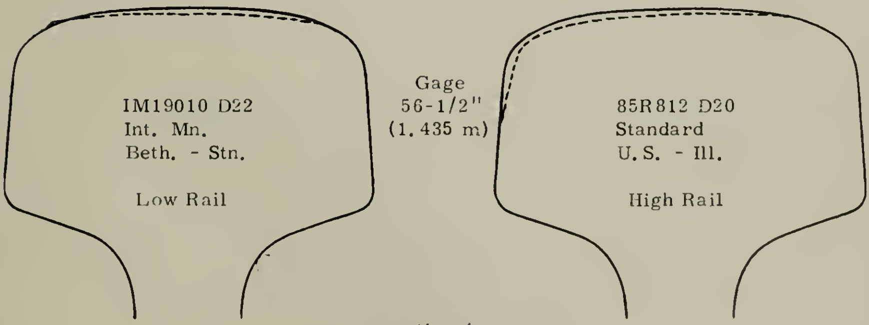
FIGURE 20

CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0
8°-08' CURVE (214.9 m RADIUS) — SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972 INSPECTED: July 31, 1973



Location 3



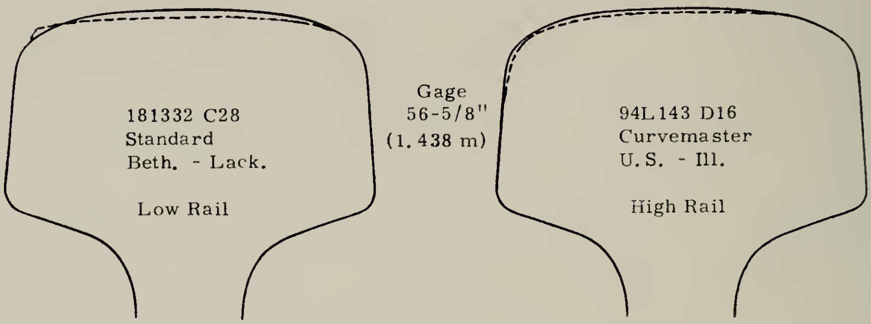
Location 4

FIGURE 21

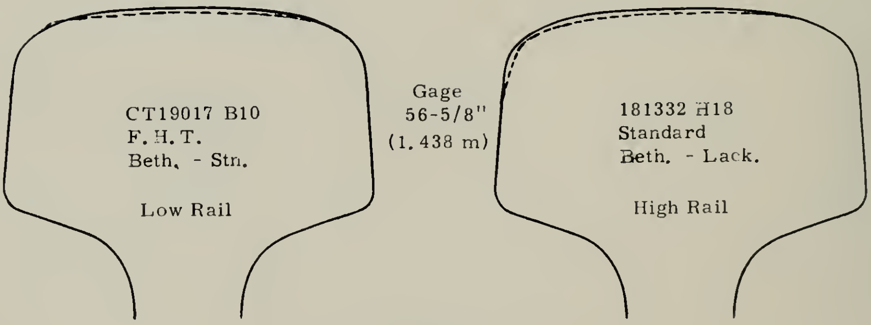
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0
8°-08' CURVE (214.9 m RADIUS) – SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 5



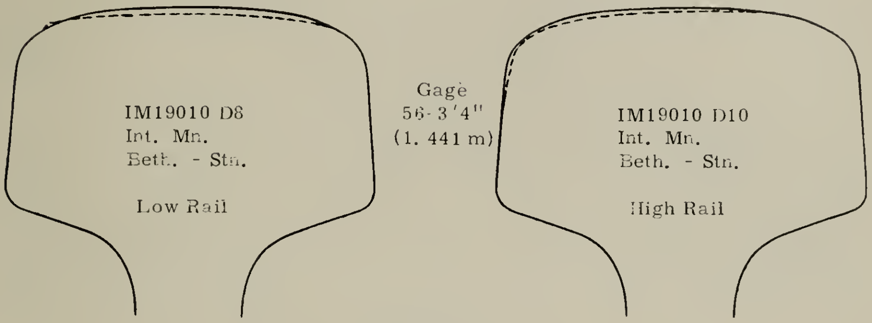
Location 6

FIGURE 22

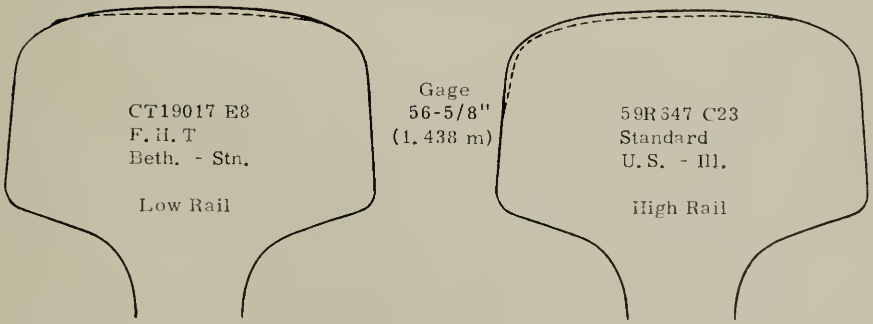
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0
8°-08' CURVE (214.9 m RADIUS) – SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1973



Location 7



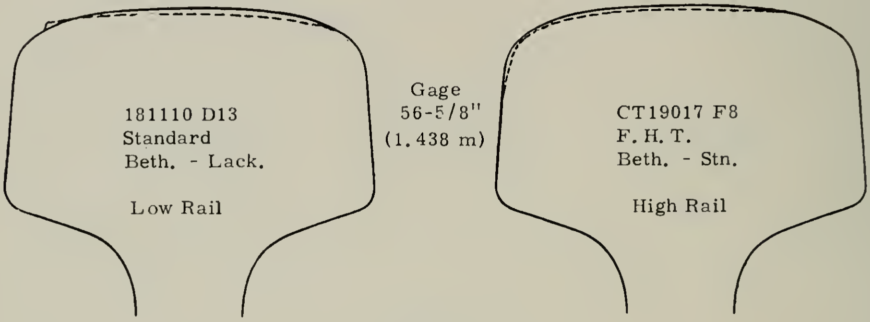
Location 8

FIGURE 23

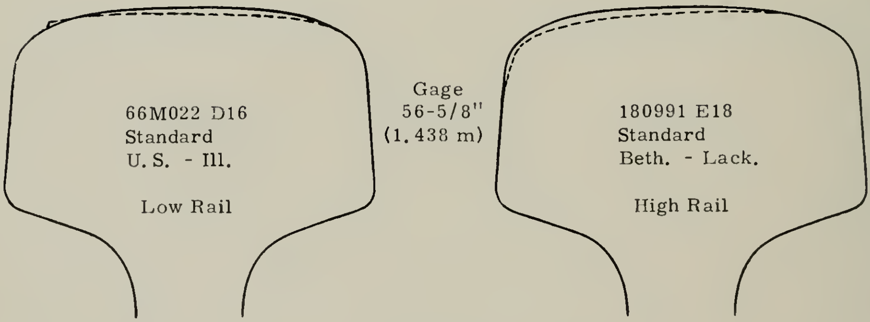
CHESSIE SYSTEM, NEAR OAKLAND, MARYLAND
TEST CURVE NO. 4 - MILE POST 235.0
8°-08' CURVE (214.9 m RADIUS) – SUPERELEVATION 5 IN. (127.0 mm)

INSTALLED: July 1972

INSPECTED: July 31, 1972



Location 9



Location 10

FIGURE 24

Advance Report of Committee 24—Engineering Education

Report on Assignment 5

Continuing Education

A. L. Sams *(chairman subcommittee)*, D. N. Cortright, J. T. Evans, L. C. Gilbert, W. P. Houwen, Jr., W. H. Huffman, H. E. Hurst, A. V. Johnston, R. G. Michael, P. S. Settle.

In this first report on the assignment, the subcommittee describes the kinds of functions performed by engineers in railway service and develops the relationship between those functions and the need for continuing education.

The new graduate engineer finds a wide variety of opportunities and challenges in the railway industry. Transportation is a vital element in our economy. The emergence of competing systems has not diminished the need for the application of scientific techniques on the railroads but has, on the contrary, helped to expand that need. Engineering is the process which develops the strategies, techniques, and equipment to make the system more effective and efficient. Without the innovation supplied by railroad engineers our railroads would long ago have succumbed to other modes of transportation. That process is needed as much today and in the future in the railway industry as it has in the past.

The railway industry attracts engineers of all disciplines. For the purpose of this report, only those involved in the Engineering Department, including signals, communications, and maintenance of way, will be considered. The functions of the Engineering Department on the railroad are to design, construct, and maintain the "fixed property," a term which is used to define all the physical property, except locomotives and cars.

Civil, mechanical, electrical, and industrial engineers find employment in railway engineering departments. Mechanical engineers are needed to plan the servicing facilities, including locomotive fueling, watering and sanding stations. They also design power plants, heating, ventilation, and air conditioning systems, and the mechanical installations for repairing cars and locomotives. Electrical engineers usually become involved in the planning and design of signalling and communication systems, and railway electrification. The development of highly sophisticated equipment in communications, signalling, hot box and dragging equipment detection, and car identification, and the growing utilization of computers have served to increase the demand for this branch of engineers in the industry. Industrial engineering organizations are becoming more prominent in railway engineering departments in response to the need for increased productivity to help offset a rise in labor costs.

Most prominent, in terms of numbers, is the civil engineer. He is to be found in all areas of the Engineering Department, except signalling and communications. Those civil engineers who specialized in structural design are usually employed in the bridge or building department. In the bridge department they design and build bridges and other structures supporting the railroad tracks. In many instances, there is ample opportunity for innovations. Similarly, those structural engineers designing larger bridges for replacement of existing structures, or in connection with the construction of a new line of railroad find many challenges to their creative ability.

Much the same is true of structural engineers in the railway building departments. Working with architects and mechanical engineers they plan and design the buildings and related facilities to house many operations. The tendency here is toward pre-engineered package equipment in order to minimize costs while providing better quality and production. There are many assignments which require ingenious solutions to engineering problems and for which knowledge of new systems and materials is most helpful. Continuing education is essential for providing skills to solve these problems.

Closely related to bridge and building engineering projects is the study of soil conditions. Specialists in soil mechanics have developed within recent years and have been of great benefit to the entire construction field. Previously, lack of knowledge about the characteristics of soils caused large expenditures to correct conditions which today's engineers can anticipate and prevent. Knowledge in this area is accumulating at a rapid rate and the designer must be kept informed of new developments.

The newest field in railway engineering is the design of methods and equipment to reduce or prevent pollution. Diesel locomotive exhaust emissions and combustion of waste materials are the principal sources of air pollution. Pollutants such as fuel and lubricating oils, detergents, chromates and other rust-inhibiting agents used in locomotive radiators and cleansing chemicals must be removed from waste and surface water before it can be discharged into sewers or open streams. Excessive noise in retarder yards, diesel locomotive shops, and testing facilities must be reduced to acceptable levels. Improved methods of disposal of old cross ties and other forms of solid waste must be found. Complete elimination of all forms of pollution, although socially desirable, is not technologically practical and acceptable pollution levels are evolving. The engineer must design and build pollution control facilities for today in such a way that they can be adapted to the environmental standards of tomorrow.

In the track design area, civil engineers prepare plans for track layouts ranging in complexity from single spur tracks to large retarder yards. Design of track layouts is not normally included in the civil engineering curriculum and the engineer must rely on his own judgment and the experience of his associates to develop optimum plans. The exchange of knowledge on use and success of new techniques and equipment within the railroad industry provides an excellent opportunity for the continuing education of engineers in this field and is expanding more rapidly than ever before.

Many engineers are more interested in field work and in the practical applications than in design. In the railway industry these men are usually assigned to a division staff as field engineers or in maintenance work. Field engineering work consists of surveying for changes or additions to facilities and the supervision of construction work. Inasmuch as maintenance is the largest single function of railway engineering, many engineers become engaged in this activity which requires a high degree of ingenuity in using modern equipment and engineering knowledge.

The functions described above are primarily professional activities. In carrying out these functions, the engineer utilizes his technical education and experience. There are many positions in the railway industry where opportunities for increasing responsibilities and salaries are available in the Engineering Department as well as in other departments. The principal handicap of an engineer in qualifying for these positions, which are primarily supervisory and managerial, is the lack of education in these non-engineering fields. The engineering college curricula do not include courses in management or supervision. This training must be acquired after graduation.

A second reason for continuing education after employment is related to the various educational backgrounds of the engineers. Many have had less than a Bachelor's Degree from an accredited engineering college. These may include the high school graduate, those who have some college education but less than a degree, recipients of a certificate as engineering technician, and graduates from a non-accredited engineering school. These individuals may be as qualified by education and experience as graduates of fully-accredited colleges but usually must serve a period of probation before being fully acceptable to do engineering work. The professional competence of these employees can be improved by their participation in technical training courses.

A third need for continuing education arises from the nature of technical activities. Through research and development new engineering knowledge is being acquired at an increasing rate. New products and processes are becoming available almost daily to aid in the solution of technical problems. If the engineer is to avoid obsolescence, he must be kept in contact with new developments in his field.

There are three needs for continuing education: (1) to give the engineer training in supervision and management areas, (2) to increase his professional competence, and (3) to keep him abreast of new developments in engineering.

Railway managements, as a general rule, encourage their employees to continue their education in order to develop more and better managers. This is especially true in the professional groups. This encouragement goes far beyond the learn-by-doing concept by which all employees may improve their performance. Enlightened managements recognize the value of continuing educational pursuits and promote it in many ways.

There are many sources of educational programs. Some are conducted on the railroad by full-time railroad personnel or by outside consultants. Some courses are offered by professional societies. Still others can be obtained from companies established for that specific purpose. Finally, the educational institutions, high schools, colleges, and universities offer courses covering a wide variety of subjects.

The in-company training program is commonly used to improve an employee's performance on his own job, to make him eligible for a new occupation, or to help promote adoption of a new system or procedure.

Professional societies become involved in educational programs sometimes as a sponsor only and sometimes as a teaching organization. One example of the former is the refresher course in preparation for the professional engineering examination sponsored by a local professional society, conducted by the staff of a nearby college with the expense paid directly by the participants. The American Management Association offers many courses throughout the country, especially those related to management development.

Some excellent additional programs are available from companies organized to provide continuing education. These companies, which operate for profit, have designed their courses to meet a large variety of needs. One such program which is especially applicable to railroad engineers is the correspondence courses.

The best source of educational program by far is that offered by colleges and universities throughout the country. They vary in scope from single courses or "short courses" to complete programs leading to advanced degrees. Many are offered at night for the benefit of students who have full-time employment. A wide variety of courses are available, both technical and non-technical.

Engineers on railroads, like those in other occupations, may find their educational backgrounds inadequate to meet their needs and goals. Opportunities to supplement their scholastic training after employment are available in many forms, and generally are well worth the effort expended as they lead to positions of greater responsibility.

Report on Assignment 8

Exchange of Professional Staffs

B. M. Davidson and C. T. Popma *(co-chairmen subcommittee 8)*, L. C. Gilbert, E. Y. Huang, J. F. Pearce, P. S. Settle, C. E. Weller, D. L. Wilson.

The following are possible subjects that could be included in undergraduate or graduate courses taught by qualified railroad personnel.

UNDERGRADUATE AND GRADUATE STUDENTS
ONE-DAY COURSE

I. Introduction
  A. General Information on Railroads
    1. Types of Trains
      a. Freight
        (1) Local
        (2) Industrial
        (3) Yard
        (4) Main Line
      b. Mail and Express
      c. Passenger
    2. Types of Equipment
      a. Cars
      b. Locomotives
        (1) Road Units Diesel
        (2) Road Units Electric
        (3) M.U. Units
          A. Metro Liners
          B. Commuter
    3. Right of Way
      a. Main Lines
        (1) Commuter
        (2) Common
        (3) Freight Only

- b. Branches
  - (1) Industrial Leads
  - (2) High-Density Feeders
  - (3) Urban Inter-yard Routes
  - (4) Low-Density Routes
- c. Yards
  - (1) Hump
    - (a) Electronic
    - (b) Manual
  - (2) Flat Switch
  - (3) Local and Industrial

(Time approximately 1 hour; slides and other visual aids should be used)

- B. Engineering Functions
  - 1. Staff
    - a. Design
      - (1) Track
        - (a) Relocation
          - 1. Temporary
          - 2. Route Change
        - (b) Crossing
          - 1. Track/Roadway
          - 2. Track/Track
        - (c) Industrial
          - 1. Operating Requirements
          - 2. Curvature Restrictions
          - 3. Grade Restrictions
          - 4. Clearance Restrictions
          - 5. Public Utility Requirements
        - (d) Yard
          - 1. Rebuild
          - 2. New Construction
      - (2) Communications and Signals
        - (a) Circuit
          - 1. C.T.C.
          - 2. Crossing
          - 3. Switch Protection
          - 4. Over Lays
          - 5. Micro Wave
          - 6. Others
      - (3) Bridges and Buildings
        - (a) Building
        - (b) Bridge
        - (c) Others
    - b. Review of Plans
      - (1) Railroad
      - (2) Outside Concern
        - (a) Industrial Development
        - (b) Pipelines
        - (c) Crossing Permits

- c. Maintenance of Records
- d. Environmental Considerations

2. Field
    - a. Construction)
        - (1) Track)
        - (2) C&S) This to be
        - (3) B&B) covered in
    - b. Maintenance) detail later.
        - (1) Track)
        - (2) C&S)
        - (3) B&B)

(Time approximately 30 minutes)

C. Physical Characteristics of Track

1. Standards
    - a. Gauge
        - (1) How arrived at
        - (2) 56½ inches
        - (3) Why important
        - (4) Variation with curves
    - b. Alignment
        - (1) Parameters
        - (2) Why important
    - c. Grade
        - (1) Limitations
            - (a) Why limited
        - (2) Importance to operation
    - d. Superelevation
        - (1) Table for Speeds
            - (a) How arrived at
        - (2) Importance to Operation
    - e. Track Centers
        - (1) Why important
    - f. Clearances
        - (1) Overhead
        - (2) Side
        - (3) Why important
        - (4) P.U.C. Standards and Authority
    - g. Electrified Territory
        - (1) How this affects above standards

(Time approximately 1 hour 30 minutes; each subject to be dealt with in detail)

II. Track Construction

A. General Types

1. Yard
    - a. Layout
        - (1) Types of Yards
        - (2) New Construction
        - (3) Rebuild on Old Yard Location

- b. Scheduling
  - (1) Critical Path
- c. Material Securement
  - (1) New
  - (2) Fit
- d. Grading
- e. Track Construction

2. Industrial
   - a. Layout
   - b. Site Preparement
   - c. Track Construction
     - (1) Panel Method
3. Main
   - a. Layout
   - b. Scheduling
   - c. Material Securement
   - d. Grading
   - e. Track Construction
4. Grade Crossings Elimination
   - a. Coordination with Government Agency
   - b. Construction
     - (1) Overpass
     - (2) Underpass
       - (a) Track Relocation
5. Grade Crossings

(Time approximately 1 hour 30 minutes)

B. Material Used in Construction of Track

1. Ties
   - a. Types
     - (1) Wood
     - (2) Laminated
     - (3) Concrete
   - b. Grades
   - c. Spacing
   - d. Function
2. Tie Plates
   - a. Types
   - b. Function
3. Rail
   - a. Sections
   - b. CWR
   - c. Conventional
   - d. Function
4. Spikes
   - a. Types
   - b. Function

5. Anchors
    a. Types
    b. Function
6. Ballast
    a. Function
7. Bars
    a. Types
        (1) Normal
        (2) Insulated
        (3) Compromise
    b. Function
8. Bolts
9. Rail Welding
10. Bonding

(Time approximately 45 minutes)

C. Material Used in Switch Construction
    1. Types of Switches
        a. Side Track
        b. Yard
        c. Main Line
            (1) Insulated
            (2) Non-Insulated
    2. Timber
        a. Sizes
        b. Material
    3. Points
    4. Stock Rails
    5. Lead Rails
    6. Frog
        a. Types
            (1) Railbound
            (2) Spring Rail
            (3) Self-guarded
            (4) Manganese Steel
    7. Switch Plates
    8. Gauge Plates
    9. Brace Plates
    10. Frog Plates
    11. Tie Plates
    12. Spikes
    13. Anchors
    14. Bars
    15. Bolts

16. Stands
17. Rods

(Construction drawings passed out would be helpful. History of switches might be given. Time approximately 30 minutes)

D. Other Track Structures
  1. Crossing Frogs
  2. Movable Point Frogs
  3. Slip Switches
  4. Gauntlet Tracks

(Time approximately 15 minutes. This not necessary; if covered, should only be done in general)

III. TRACK MAINTENANCE
  A. General Information
    1. Largest Part of Engineering Dollar
    2. How Done
      a. Maintenance Gangs
        (1) Mechanization
      b. Production Gangs
        (1) Mechanization
    3. How Programmed
    4. Contract Help
      a. Rail Grindings
      b. Ballast Cleaning
      c. Brush Spray
      d. Weed Spray
      e. Rail Testing
      f. Ballast Cleaning

(Time approximately 15 minutes)

  B. Criteria
    1. Gauge
      a. Variances allowed and why
      b. When dangerous
      c. Wheel and axle relationship
      d. What causes widening of gauge
      e. What causes rail corrugation
    2. Surface
      a. Variances allowed and why
      b. When dangerous
      c. Car design in relation to surface
      d. What causes loss of surface
    3. Line
      a. Variances allowed and why
      b. When dangerous
      c. Relationship to surface and gauge

(Time approximately 1 hour. Details as to how criteria were developed should be given)

C. Methods of Maintenance
  1. Regular Maintenance Gangs
    a. Section)
    b. Welder)
    c. I&R) Functions of each to be described
  2. Production Maintenance Gangs
    a. Tie
      (1) Types
      (2) Organization
      (3) Function
    b. Surfacing
      (1) Types
      (2) Organization
      (3) Function
    c. Rail
      (1) Types
      (2) Organization
      (3) Function
    d. Special
      (1) Type
      (2) Organization
      (3) Functions

(Time approximately 1½ hours. Slides or mechanized equipment used by various gangs should be used with this presentation)

UNDERGRADUATE STUDENTS
ONE WEEK COURSE

If time was made available to the railroads to give a one-week course, qualified individuals would have to be chosen from within the industry. These individuals should be completely knowledgeable on their subject and be able to present it in such a manner that the students could relate the material being presented with their own academic studies. A few of the possible subjects that could be used as a basis for presentation are:

1. Track construction methods
2. Continuous welded rail
3. Soil, its effects on roadbed stability
4. Rail defects, how they are found
5. Management techniques and methods
6. Car and track interaction
7. Derailment causes and ways to prevent
8. Electrification, pros & cons
9. Branch construction & maintenance
10. Mass transportation

The subjects are numerous and the selection should be determined by both the participating railroads and the faculty members of the participating schools.

The one underlying goal of either a one-hour, one-day or one-week class should be the imparting for the student the fact that the railroad industry is an engineering-oriented business with numerous interesting and rewarding jobs, highly suited to a man with an engineering degree.

THE AMERICAN RAILROADS' ROLE IN TODAY'S TRANSPORTATION

1. Percent of American freight that moves by rail.
2. Kinds of freight that moves by rail.
3. Equipment.
4. Energy conservation.
5. Ecological impact.
6. Inherent advantages of rail.
7. Commuter traffic.
8. Passenger service.
9. Corridor movements.
10. Unit trains.

TRACK STRUCTURE

1. Material
    a. Subsoil
    b. Sub-ballast
    c. Ballast
    d. Ties
    e. Plates
    f. Spikes
    g. Rail
    h. Anchors
    i. Bars
    j. Bolts
    k. Bonds
2. Parameters
    a. Gauge
    b. Surface
    c. Line
3. Switches
4. Crossing frogs
5. Gauntlet tracks

TRACK MAINTENANCE

1. Percent of M of W budget
2. Reasons for
3. Causes of
4. Parameters
5. Cycle maintenance

6. Spot repair
7. Rail renewal
8. Methods of doing

ROUTE DESIGN

1. Main Line
    a. Relocation
    b. New installation
2. Yard
    a. Rebuild
    b. New installation
3. Industrial
4. Grade restrictions
5. Clearance restrictions
6. State utility requirements
7. Curvature restrictions

ROUTE CAPACITY

1. Restricting Factors
    a. Speed Limit
    b. Grade
    c. Curvature
    d. Signaling
    e. Detours
2. How to figure
3. How to increase
4. Optimum design

INTERMODAL TRANSPORTATION

1. Transportation modes
    a. Rail
    b. Truck
    c. Plane
    d. Barge
    e. Pipe Line
    f. Conveyor
    g. Ship
2. What accomplished to date
    a. Piggyback
    b. Canadian Pacific
3. Possible organization structure
4. Advantages

Advance Report of Committee 16—Economics of Plant, Equipment and Operations

Report on Assignment 5

Economics of Freight Cars with Characteristics Approaching the Limits of Acceptable Designs

D. H. Noble *(chairman subcommittee)*, R. E. Ahlf, C. Bach, R. H. Dunn, G. R. Gaspard, A. J. Gellman, E. C. Honath, R. P. Hoffman, J. H. Marino, W. L. Paul, G. Rugge, L. K. Sillcox, J. R. Wilmot.

SCOPE: To investigate the economic impact of operating specialized freight cars of unusual design having relatively high gross weights, relatively high axle loadings, multiple trucks, articulated couplings, excess width, and/or unusual length. This study should include the impact on switching operations, train operations, maintenance of way and structures facility requirements and competition in transportation markets.

Free interchange of freight cars throughout the country is a key factor in the ability of railroads to meet their commitment to efficient transportation. In no other industry are production tools and capital investment so freely exchanged with competitors, yet the railroad freight car is completely compatible on any line in almost any train.

This free interchange is possible only because certain basic restrictions have been placed on car design. In effect, an envelope has been drawn around the extreme limits of weight, height, width and length so that operating personnel can be assured that cars offered in interchange will move freely and safely in their trains.

These specifications are contained in several publications, and the intent of this report is simply to summarize the general requirements and to outline the situations which must be considered when cars are operated that approach these limits.

It is not the intent of this report to offer quantitative solutions to the problems inherent in the operation of cars with characteristics approaching design limitations, but rather to outline what those limitations are and suggest some of the conditions that can develop.

More detailed information can be obtained from the publications which are mentioned.

All cars offered in interchange between railroads must meet the requirements of the *Interchange Rules* issued by the Association of American Railroads. This publication is furnished in two volumes, each of which is revised annually. The Field Manual portion is primarily intended for line mechanical supervision and is devoted to specific maintenance and inspection requirements. The Office Manual covers design, certification requirements and billing instructions. Since different portions of the same rule appear in each manual, it is important to refer to both volumes when in doubt.

The keystones of the Interchange Rules are contained in Rule 88-A-1 which reads:

> "No car of untried type, built new or altered, shall be offered or accepted in interchange until its size, capacity and design has been approved by the Transportation and Mechanical Division of the Association of American Railroads. The same principle applies to trucks or major components of the car body, where strength, interchangeability of the parts, and general utility of the car are involved."

and in Rule 88-B-1 reading:

> "All cars built new on or after January 1, 1966 for interchange service must conform to Specifications for Design, Fabrication and Construction of Freight Cars. In addition to the foregoing, tank cars must conform to the AAR Specifications for Tank Cars."

These rules effectively bind the designer and builder to limitations that meet the goals of free interchange. At the same time, he has the ability to propose new and untried designs through the Mechanical Division of the AAR, and there are provisions permitting evaluation and testing.

Physical Limits

The limiting dimensions of a freely interchangeable car are:

Maximum height: 15 ft 6 in above the rail
Maximum width: 10 ft 8 in
Minimum clearance of trucks, brake rigging and car body: 2½ in above the rail (Effective January 1, 1980, the minimum clearance is increased to 2¾ in above the rail).

These limits do not follow a purely rectangular shape but must fit within the composite diagram identified as Plate C. Plate C, adopted in 1963 (revised 1965, 1966, 1967 and 1968), is a liberalized version of slightly more restrictive clearances than are shown in Plate B. Plate B cars are intended to be handled freely over all rail lines; Plate C cars are acceptable except where specifically restricted in the publication, *Railway Line Clearances.* Both of these plates are published in the *AREA Manual,* the *Official Railway Equipment Register,* the *Manual of Standard and Recommended Practices* of the AAR Mechanical Division and *Railway Line Clearances.*

For rapid identification, the design specification is identified by a stencil located to the right of the reporting marks on each side of the car. A Plate B car has no stencil. A Plate C car has a 10-in x 10-in square background with the wording "Plate C" stencilled. A car exceeding Plate C, but less than 16 ft 10 in above the rail, has a 13-in-diameter circle background with the wording "Exceeds Plate C" stencilled. In general, the operating man can identify the free running Plate B car by no stencil, the more restricted Plate C car by a square stencil to the right of the reporting marks, and the more restricted high car by a circular stencil.

Proposals are under consideration to add Plates E and F for limited interchange, allowing height above the rail as great as 17 ft.

Cross-section dimensions themselves cannot fully identify clearances. As car lengths increase, the swingout at car ends and at the center of the car increases, dependent upon distance between truck centers, car length and degree and type of curvature. For purposes of design, Plate C clearances are dependent upon a base car with 46-ft 3-in truck centers on which the swingout at ends of car does not exceed the swingout at the center of the car on a 13° curve. As truck center distance increases, the allowable car width is reduced as shown in tables accompanying Plates B and C.

Complementing the Plate C clearance dimensions are the AREA recommended clearances for new construction as shown in the *AREA Manual.* Local laws or regulations also limit physical clearances in many areas, and since these govern, they should be verified initially.

Weight Restrictions

Wheels, axles and running gear are designed to withstand certain stress levels, and loaded car weight on rail is limited to 65,750 lb per axle for unstricted interchange. For a four axle car, this permits a gross weight on rail for car and lading of 263,000 lb. A car meeting this design is referred to as a nominal 100-ton car since average car tare weight is in the neighborhood of 30 tons.

For the engineer designing roadway structures, it can generally be assumed that these loads will be transmitted to the rails through 36-in wheels with truck axle spacings of 5 ft 8 in. Additional gross weight may be added by increasing the number of axles, with a 65,700-lb increase allowed for each axle. The publication, *Official Equipment Register,* lists all flat cars with capacities of over 200,000 lb in a special section that includes number of axles, wheel spacings and permissible load limits. Extremely heavy loads of over 300 tons are becoming increasingly common as the sizes and weights of nuclear reactors, pressure vessels and turbine components increase. Present maximum weights per piece approach 500 tons, but car designs are under consideration for 700 ton pieces.

A limited number of four axle cars have been built with nominal 125 ton trucks. These are designed to support a gross rail load of 315,000 lb. Since this exceeds 65,700 lb per axle, the cars are not acceptable in free interchange but may be offered to connecting railroads on a special agreement basis. Wheels on these cars are 38 in. in diameter and axle spacing is usually 6 ft. In addition, wheel loads producing high stresses are frequently found in cars with 30-in and 33-in wheels. Such intensive stresses can cause rapid destruction of rail surfaces.

The "Specifications for New Car Construction" limit the maximum weight per coupled foot to 6,000 lb, making the minimum length of a 100 ton car slightly under 44 ft.

The maximum length car permitted in general interchange service today is 89 ft 4 in as exemplified by the TOFC or auto rack car. Truck centers on these cars are 62 to 66 ft.

The design of a freight car must be such that the center of gravity of car and load does not exceed 98 in above the rail. In general, a center of gravity this high is normally found only in loaded covered hoppers, hoppers and highside gondolas used for bulk materials. Certain excessively high loads on open top cars may exceed the design limit, and such loads are generally subject to special handling dependent upon the rules of the individual railroad. Whenever excessively high loads are experienced, the center of gravity should be calculated and appropriate restrictions imposed.

Modern cars with long travel springs and snubbing devices on the trucks generally exhibit stable running characteristics. However, whenever cars are acquired that approach the maximum center of gravity limits with truck centers close to normal rail lengths, the possibility of harmonic rocking must be considered. These characteristics can be analyzed with available computer programs.

Design Considerations

Despite the restraints imposed by the various rules, specifications and standards, car designers have exhibited an abundant ability to develop new and ingenious solutions to market needs. The design limits have evolved empirically as experience has grown, but they are under constant pressure as cost conscious railroads and shippers search for economies.

The strongest pressure affecting operating characteristics results from a desire to increase pay load per car. From a shipper's standpoint, this creates savings in loading costs, permits the use of incentive rates to reduce transportation bills and offers corollary savings in cars that must be handled in his plant, demurrage expense and inventory expense.

For the railroads, the intent of additional tonnage per transportation vehicle improves the ratio of investment to revenue, creates potential transportation savings and offers an important competitive advantage, the ability to develop incentive rates to encourage shippers to load heavier.

Coupled with this is the growth of professional physical distribution departments in our customers' organizations and the development of railroad marketing. The railroad car is increasingly viewed as a part of the customers' production and inventory cycle, and the user demands a vehicle that can be integrated into his material handling practices. Railroad marketing is faced with the need to provide economical equipment that will attract business, improve the net return and not be made obsolete if one customer changes products or processes.

From these conflicts rise the compromises found in today's equipment, and the greatest pressures to push beyond current design criteria.

The goal of increased lading weight can only be achieved by increased volume, and since car width is firmly restricted, only height and length are available. With certain exceptions, the car load limit is reached long before the limits of the 89 ft 4 in maximum length. However, track space is expensive, both in an industrial plant and on a railroad. The tendency is to design for maximum height and to hold car length to a minimum. The designer must recognize that few cars are committed indefinitely to one product, and his calculations must include a factor of safety for products which can increase the center of gravity.

Operating Characteristics

The factors which most affect train and yard operations are weight, length and height. While weight can be directly dealt with in design and maintenance of track and structures, the sudden addition of a high volume of heavy cars can result in rapid increase in maintenance costs and rail failures. If adequate allowance is included in the rate charged for such traffic, the problems associated with the traffic are controllable.

Long cars create problems in train operation. The derailing force on a car is dependent upon the coupler angle. Cars with long truck centers have greater end overhang, which increases the amount of lateral force between two coupled cars on a curve. The force is greatest when a long car is coupled to a car with short overhang and when the long car is subject to high draft or buff forces. When the ratio of lateral force to car weight decreases to 0.82, wheel lift can occur.

From a practical standpoint these factors influence the tracking capabilities of a long car.

a. Its location in the train. A car towards the rear will be subject to less draft or buff force.

b. The type of car to which it is coupled. A long car generally is subject to less force when coupled to a long car.

c. The car weight. A heavy car requires greater lateral force to develop the same critical ratio as a light car.

d. The amount of tractive effort or pulling force. Derailing tendencies will be greater at slow speed, full throttle operation as would occur on an ascending grade.

Increased car length creates distinct problems. The Plate B or Plate C diagram will require a long car to be narrower than a short car, and this reduces the swing-out at the ends and center of a car. Despite this, a long car does have greater clearance requirements, especially on sharp curves.

Long cars, including cushion cars with extended sliding sills, are more likely to experience passed couplers during switching operations. Any track layout that prevents alignment of couplers will be accentuated with long cars. This will not only increase handling time and delay yard and switching operations, but is a frequent source of damage to the car end structure and to the uncoupling lever. The latter is a federal safety defect that must be corrected on the repair track.

Long cars also must frequently be placed in trains out-of-block, which increases switching costs, or train weight must be reduced where long cars are handled near the head end of a train in mountain territory. These restrictions are to reduce the frequency and probability of derailing long cars. The lateral forces where there is a combination of heavy grades and sharp curves will accentuate the tendency of long cars to lift their outer wheels from the rail or to ride up on their inside flanges. Either of these actions greatly increases the potential for derailments.

Cars with a high center of gravity have a natural tendency to rock with greater amplitude. Every car has a natural frequency and depending upon the timing of the force creating the rock, a harmonic situation can develop so that each impulse of force hits at a critical moment and each rock is progressively more severe. Carried to its limit, the car will begin to experience wheel lift, and derailment may occur. The force creating rocking is generally the difference in cross level at the rail joints, and with a normal 50-ft car, the harmonic condition develops in the range of 15 to 25 mph.

Rock and roll is a serious problem and became critical following the development of 100-ton high-cube covered hoppers, hopper cars, and gondolas with high centers of gravity. Since it is dependent upon speed, car suspension, truck center length and track conditions, the proper combination of any of these variables can create a series of sudden, difficult-to-explain derailments. It is best prevented by insistance on suitable truck snubbing devices on high center of gravity cars, and close attention to track conditions where such cars operate.

The natural stiffness of the car body will affect its rocking tendencies. A flexible car will attenuate the rocking force whereas a stiff car will accentuate such force.

References

Field Manual of the Interchange Rules, Mechanical Division Association of American Railroads

Office Manual of the Interchange Rules, Mechanical Division Association of American Railroads

Specifications for the Design, Fabrication and Construction of Freight Cars, Mechanical division, Association of American Railroads

Manual of Standards and Recommended Practices, Mechanical Division, Association of American Railroads

Railway Line Clearances, Railway Equipment and Publication Company, 424 West 33 St., New York, N. Y.

Official Railway Equipment Register, Railway Equipment and Publication Company

DIRECTORY
CONSULTING ENGINEERS

FRANK R. WOOLFORD

Engineering Consultant—Railroads

24 Josepha Ave.
San Francisco, Ca. 94132
(415) 587-1569

246 Seadrift Rd.
Stinson Beach, Ca. 94970
(415) 868-1555

WN

Westenhoff & Novick, Inc.

Consulting Engineers

Civil—Mechanical—Electrical

Fixed & Movable Bridges
Soils, Foundations, Buildings
Structural & Underwater Investigations
Planning, Feasibility, Design, Inspection

222 W. Adams St., Chicago, Ill. 60606

New York Washington Panama

HAZELET & ERDAL

Consulting Engineers

Design Investigations Reports
Fixed and Movable Bridges

150 So. Wacker Dr., Chicago, Ill. 60606
Louisville Cincinnati Washington

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF

Feasibility studies and design services for

- Bus and rail transit
- Regional and urban planning
- Soils and foundations
- Structures
- Environmental impact studies
- Terminals
- Parking
- Tunnels
- Utilities

Offices in 26 cities 816 474-4900
1805 Grand Avenue, Kansas City, Missouri 64108

KIRKHAM MICHAEL

Consulting Engineers

Bridges, Relocations, Land Development

Omaha • Minneapolis • Rochester
Fargo • Sioux Falls

CLARK, DIETZ AND ASSOCIATES—ENGINEERS, INC.

Consulting Engineers

Bridges Structures, Foundations, Industrial Wastes and Railroad Relocation

211 No. Race St., Urbana, Ill.

Sanford, Fla. Memphis, Tenn.
Jackson, Miss. St. Louis, Mo.
Chicago, Ill.

MODJESKI AND MASTERS

Consulting Engineers

Design, Inspection of Construction & Inspection of Physical Condition of Fixed & Movable Railroad Bridges

P.O. Box 2345, Harrisburg, Pa. 17105
1055 St. Charles Ave., New Orleans, La.

HARDESTY & HANOVER

Consulting Engineers

MASS TRANSPORTATION

Highways • Railways
Bridges—Fixed and Movable
Design • Resident Inspection
Studies • Appraisals

101 Park Ave., New York, N. Y. 10017

THOMAS K. DYER, INC.

Consulting Engineers

Railroads—Transit Systems
Track, Signals, Structures

Investigations and Feasibility Reports
Planning, Design, Contract Documents

1762 Massachusetts Avenue
Lexington, Mass. 02173

DCO The De Leuw, Cather Organization

CONSULTING ENGINEERS

165 W. WACKER DRIVE • CHICAGO 60601

SUBWAYS • RAILROADS • SIGNAL SYSTEMS
PUBLIC TRANSIT • TRAFFIC • PARKING
HIGHWAYS • BRIDGES • PORT DEVELOPMENT
COMMUNITY PLANNING • URBAN RENEWAL
MUNICIPAL WORKS • INDUSTRIAL • AIRPORTS
ENVIRONMENTAL SCIENCE AND ENGINEERING

BOSTON • BUFFALO • NEWARK • NEW YORK
OKLAHOMA CITY • PHILADELPHIA • PORTLAND, OR.
SAN FRANCISCO • SEATTLE • WASHINGTON, D.C.

IECO

INTERNATIONAL ENGINEERING COMPANY, INC.

CONSULTING ENGINEERS

RAILWAYS HIGHWAYS
BRIDGES TUNNELS
ROUTE LOCATION
SHOP FACILITIES

(415) 397-4071
CABLE • INTERENGCO 220 MONTGOMERY ST.
SAN FRANCISCO • CALIFORNIA 94104

404–577–5600 523–3232

RILEY, PARK, HAYDEN & ASSOC., INC.

Consulting Engineers

101 Marietta Street, N.W.
Atlanta, Ga. 30303

Engineers
Designers Planners

**PARSONS
BRINCKERHOFF
QUADE
DOUGLAS**

Route Location, Shop Facilities, Container/Bulk Cargo, Handling Utilities, Bridges, Tunnels, Evaluations, Appraisals, Supervision

ONE PENN PLAZA, NEW YORK, NY 10001
Boston • Denver • Honolulu
San Francisco • Trenton

RALPH WHITEHEAD & ASSOCIATES

Consulting Engineers

**Bridges, Buildings, Highways,
Railroads, Airports**

**1945 RANDOLPH ROAD
CHARLOTTE, NORTH CAROLINA 28207**

R.W. BOOKER & ASSOCIATES, INC.

ENGINEERS ARCHITECTS PLANNERS

**1139 OLIVE ST. ST. LOUIS, MISSOURI 63101
LEXINGTON, KENTUCKY FORT WORTH, TEXAS**

PORTER AND RIPA ASSOCIATES, INC.

ENGINEERING · PLANNING · ARCHITECTURE

Design · Inspections · Reports
Planning · Structures
Environmental Studies

208 Madison Avenue, Morristown, New Jersey 07960

SVERDRUP & PARCEL AND ASSOCIATES, INC.
800 No. Twelfth Blvd. St. Louis, Mo. 63101

- *DESIGN*
- *PLANNING*
- *CONSTRUCTION MANAGEMENT*

Boston, Charleston, Gainesville, Jacksonville,
Nashville, New York, Phoenix,
San Francisco, Seattle, Washington, D.C.

CONSULTING ENGINEERS

SOROS ASSOCIATES

Consulting Engineers

Transfer Terminals & Ports For Dry Bulks,
Liquids & Containers—Waterfront Structures
Materials Handling Systems

575 Lexington Ave.
New York, N. Y. 10022
(212) 421–0400

**Rio de Janeiro Santiago, Chile
Sydney, Australia**

R. G. "SLIM" SIMMONS

Railroad Consultant

3009 George St.
Franklin Park, Ill. 60131
(312) 678–7321

30 Jackson St.
Denver, Colo. 80206
(303) 321–0902

THE KEN R. WHITE COMPANY
TOTAL CONCEPT
ENGINEERING SERVICE

- BRIDGES—FOUNDATIONS
- ENVIRONMENTAL STUDIES
- FEASIBILITY STUDIES
- PHOTOGRAMMETRY—MAPPING
- PLANNING—INDUSTRIAL PARK
- RELOCATIONS
- TRANSPORTATION

3955 E. Exposition Avenue
Denver, Colorado 80209
Phone (303) 744-1861

HELENA • PHOENIX • ATLANTA • MIAMI • HONOLULU

McCormick, Taylor and Associates, Inc.

Consulting Engineers

Structural • Transportation
Public Works • Support Service

351 E. Conestoga Rd.
Strafford, Pa. 19087
(215) 687-6311

Suburban Station Bldg.
Philadelphia, Pa. 19103
(215) LO 9-2400

A. J. HENDRY, INC.
CONSULTING ENGINEERS

SIGNALS • COMMUNICATIONS • AUTOMATION • ELECTRIFICATION
RAILROADS • RAIL TRANSIT

SUITE 810 OSBORN BUILDING
ST. PAUL, MINNESOTA 55102
(612) 222 2787

SPAULDING ENGINEERING CO.

CONSULTING ENGINEERS
MEMBER
AMERICAN CONSULTING ENGINEERS COUNCIL

1821 UNIVERSITY AVENUE
ST. PAUL, MINNESOTA 55104
PHONE 612/644–5676

TURNER ENGINEERING COMPANY

(SAWYER–PIEPMEIER)

RAILROAD ENGINEERING

306 GAY ST.
NASHVILLE, TENNESSEE 37201
615–244–2144
ALBANY, NY 518–456–1994

GOOD TRACK
GOOD SERVICE

COAST TO COAST...

Let Speno show you the way to get significantly more ton miles of service from your rails. Send for FREE Booklets on Speno Ballast Cleaning and Speno Rail Grinding.

Ballast Cleaning • Rail Grinding

"Just Ask the Railroads That Use Our Services"

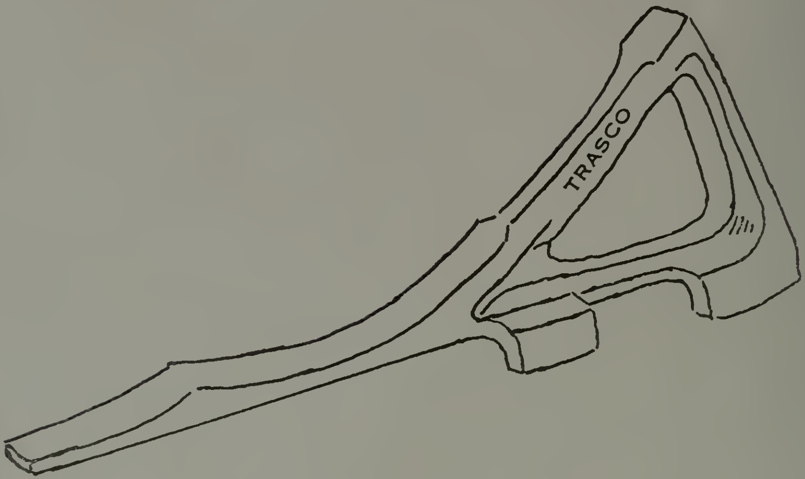
Frank Speno Railroad Ballast Cleaning Company, Inc.
306 North Cayuga St., Ithaca, New York 14850
Clark St., Box 219 East Syracuse, New York 13057

Speno International, S. A.
22 Parc Chateau Banquet, Geneva, Switzerland
(For Rail Grinding Outside the North American Continent)

MEMBER RPI

IEC-Holden Ltd.
8180 Côte de Liesse Road.,
Montreal, 376 P. Q., Canada

TRASCO Track Skates



Preferred by skatemen
Light
Tough
Balanced hand hold
No curl tongue

TRACK SPECIALTIES
COMPANY
Box 729 Westport, Conn.

American Railway Engineering Association—Bulletin

Bulletin 650
Proceedings Volume 76*

November–December 1974

CONTENTS

PART 1—MANUAL RECOMMENDATIONS

Roadway and Ballast (1) ---------- 145
Buildings (6) ---------- 167
Concrete Structures and Foundations (8) ---------- 205
Highways (9) ---------- 219
Engineering Records and Property Accounting (11) ---------- 224
Environmental Engineering (13) ---------- 226
Timber Structures (7) ---------- 232
Clearances (28) ---------- 233
Special Committee on Concrete Ties ---------- 238
Steel Structures (15) ---------- 240

PART 2—REPORTS OF COMMITTEES

Highways (9) ---------- 249
Engineering Records and Property Accounting (11) ---------- 259
Yards and Terminals (14) ---------- 267

Directory of Consulting Engineers ----------278–1

---

* Proceedings Volume 76 (1975) will consist of AREA Bulletins 649, September–October 1974; 650, November–December 1974; 651, January–February 1975; and 653, June–July 1975 (Technical Conference Report issue). Blue-covered Bulletin 652, April–May 1975 (the Directory issue), is not a part of the Annual Proceedings of the Association.

BOARD OF DIRECTION
1974–1975

President

R. F. Bush, Chief Engineer, Erie Lackawanna Railway, Midland Bldg., Cleveland, OH 44115

Vice Presidents

J. T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, 500 Water St., Jacksonville, FL 32202

W. J. Jones, Engineer Maintenance of Way and Structures, System, Southern Pacific Transportation Company, 1 Market St., San Francisco, CA 94105

Past Presidents

R. M. Brown, Chief Engineer, Union Pacific Railroad, 1416 Dodge St., Omaha, NE 68179

D. V. Sartore, Chief Engineer—Design, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101

Directors

B. G. Anderson, Assistant Vice President—Engineering, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101

John Fox, Assistant Chief Engineer, Canadian Pacific Rail, Windsor Station, Montreal, PQ H3C 3E4

C. E. Weller, Assistant Vice President—Engineering, Chicago, Rock Island & Pacific Railroad, LaSalle St. Station, Chicago, IL 60605

B. J. Gordon, Chief Engineering Officer, Penn Central Transportation Company, 6 Penn Center Plaza, Room 1640, Philadelphia, PA 19104

R. W. Pember, Chief Engineer, Design and Construction, Louisville & Nashville Railroad, P. O. Box 1198, Louisville, KY 40201

E. Q. Johnson, Senior Assistant Chief Engineer, Chessie System, P. O. Box 1800, Huntington, WV 25718

W. E. Fuhr, Assistant Chief Engineer—Staff, Chicago, Milwaukee, St. Paul & Pacific Railroad, Union Station, Room 898, Chicago, IL 60606

B. E. Pearson, Chief Engineer, Soo Line Railroad, Soo Line Bldg., Room 1520, Minneapolis, MN 55440

P. L. Montgomery, Manager Engineering Systems, Norfolk & Western Railway, 8 N. Jefferson St., Roanoke, VA 24011

E. C. Honath, Assistant General Manager Engineering, Western Lines, Atchison, Topeka & Santa Fe Railway, 900 Polk St., Amarillo, TX 79101

Mike Rougas, Chief Engineer, Bessemer & Lake Erie Railroad, P. O. Box 471, Greenville, PA 16125

J. W. DeValle, Chief Engineer Bridges, Southern Railway System, 99 Spring St., S. W., Atlanta, GA 30303

Treasurer

A. B. Hillman, Jr., Chief Engineer, Belt Railway of Chicago, 6900 S. Central Ave., Chicago, IL 60638

Executive Director

Earl W. Hodgkins, 59 E. Van Buren St., Chicago, IL 60605

Assistant to Executive Director

N. V. Engman, 59 E. Van Buren St., Chicago, IL 60605

Administrative Assistant

D. F. Fredley, 59 E. Van Buren St., Chicago, IL 60605

Published by the American Railway Engineering Association, Bi-Monthly, January–February, April–May, June–July, September–October and November–December, at
59 East Van Buren Street, Chicago, Ill. 60605

Second class postage at Chicago, Ill., and at additional mailing offices.
Subscription $15 per annum.

Copyright © 1974
by the
American Railway Engineering Association
All rights reserved.

No part of this publication may be reproduced, stored in an information or data retrieval system, or transmitted, in any form, or by any means—electronic, mechanical, photocopying, recording, or otherwise—without the prior written permission of the publisher.

JAN 2 2 1975

PART 1

MANUAL RECOMMENDATIONS

All the recommendations submitted by committees for adoption and publication in the 1975 Supplement to the AREA Manual for Railway Engineering are printed in this issue of the Bulletin. These recommendations will be formally submitted for review and approval to the Board Committee on Publications and the AREA Board of Direction. Comments or objections by Members regarding any of these recommendations should be submitted to the Executive Manager not later than FEBRUARY 14, 1975.

Manual Recommendations

Committee 1—Roadway and Ballast

Report on Assignment 2

Ballast

C. E. Webb *(chairman, subcommittee)*, R. H. Beeder, E. W. Burkhardt, J. W. Dykes, H. K. Eggleston, G. E. Ellis, R. D. Hellweg, J. K. Lynch, H. E. Moore, F. P. Nichols, Jr., R. H. Peterson, W. B. Peterson, R. H. Uhrich.

Your committee submits for adoption the following revisions to Part 2, Chapter 1 of the Manual:

Pages 1–2–2 to 1–2–4, incl.

SPECIFICATIONS FOR PREPARED STONE, SLAG AND GRAVEL BALLAST

Page 1–2–2, Art. 3 (b)—Delete present Note under Art. 3 (b) and substitute: *Note:* The percentages of wear determined on samples from the same source by ASTM Methods C 131, C 535, or either method using different gradings, have no known consistent relationship to one another. Tests have shown that losses under C 535 were about 5% higher than under C 131 on slag ballast, were somewhat higher on carbonate materials, and tended to be lower on igneous rocks. Where known service records or previous test data make it economically advisable to permit percentages of wear in excess of 40% when tested by the prescribed method, such higher losses may be permitted in the special provisions; however, the engineer is warned against permitting losses in excess of 50% without thorough investigation of all factors.

Page 1–2–4, Art. 8 (f)—Delete present information and substitute:

(f) The resistance to abrasion shall be determined in accordance with the current ASTM Method of Test, designation C 131 or C 535, using the standard grading most nearly representative of the size of ballast specified.

Report on Assignment 9

Vegetation Control

H. C. Archdeacon *(chairman, subcommittee)*, H. E. Bartlett, R. H. Bogle, Jr., F. B. Grant, T. J. Hernandez, P. R. Houghton, D. N. Johnston, J. H. Kirch, G. D. Santolla, W. H. Stumm.

Your committee recommends for adoption and publication in Part 9, Chapter 1 of the Manual the following data pertaining to railroad vegetation control: Terminology; Preparing a Vegetation Control Program; Executing a Vegetation Control Program; Evaluating Results of a Vegetation Control Program; Table 1—Types and Characteristics of Herbicides; and Table 2—Herbicide Toxicity Ratings. This material is intended to replace present Manual material on pages 1–9–1 through 1–9–14.

9.1 TERMINOLOGY

ACRE—Along railroad right-of-way, approximately 8 ft wide by 1 mile long. (Actually 8 ft, 3 in wide).

ABSORPTION—Penetration and retention of herbicide through foliage or stems.

ADSORPTION—The adhesion of molecules of chemical to solids.

BASAL—Lower portion of bare area of tree at groundline or root-collar.

BROADLEAF—Plants with broad, usually compound leaves. Mostly low growing, 1-3 ft, but some species such as giant ragweed can reach 12 ft.

BRUSH—Woody plants growing where they are not wanted.

BRUSH ACRE—A solid acre of brush of varying height, generally 8–10 ft.

CARRIER—A material with which herbicides are mixed and applied.

CHLOROSIS—Chemical plant injury evidenced by whitening or yellowing of the foliage.

CONIFER—A tree producing seed in a cone, generally having evergreen needles.

DECIDUOUS—Having leaves which fall off seasonally, usually in Autumn.

DILUTION—Ratio of active ingredients to the carrier in which it is mixed.

DOSAGE—Amount of active ingredient or formulated product per acre.

DRIFT—Airborne movement of small particles of spray solution to areas outside of the spray pattern during application.

FLAMMABILITY—Susceptibility of a herbicide or treated area to ignition.

FOLIAGE—Leaf area of a plant.

FORMULATION—Blending of a herbicidal mixture.

GRASSES—Plants characterized by narrow leaves with parallel veins, by leaves composed of blade, sheath, and ligule and by jointed stems and fibrous roots.

HERBICIDE—Chemical for control of undesired vegetation.

(a) CONTACT—Controls top growth by chemical destruction of plant tissue.

(b) SYSTEMIC—Mode of action depends upon translocation through leaf and stem.

(c) RESIDUAL—A herbicide that persists in the environment for at least 3 months. Controls by absorption through the roots.

HORMONE—A plant growth regulator, usually a phenoxy-type chemical.

NON-SELECTIVE HERBICIDE—Controls all species.

PHENOXY—A hormone herbicide, usually a formulation of 2, 4-D, 2, 4, 5-T or their propionic homologs.

PROSTRATE—Flat on the ground.

RATING—The degree of control obtained expressed numerically.

RHIZOME—A sprout from a node on an elongated, underground stem, from which a new plant can develop.

SELECTIVE HERBICIDE—Controls only certain types of plants.

SPECIES—A subdivision of a genus. A group of closely related plants descendent from the same stock.

SURFACTANT—Surface active agent used for more uniform coverage of the herbicide on the plant, and to increase absorption.

TRANSLOCATION—The movement of chemical from leaves to other parts of the plant.

VINES—Any plant which climbs by tendrils or other means, or which trails or creeps along the ground. Stems can be woody or succulent.

9.2 PREPARING A VEGETATION CONTROL PROGRAM

9.2.1 VEGETATION CONTROL METHODS

The methods employed to control vegetation on railroad rights-of-way may be grouped into three general categories: controlled burning, mechanical control and chemical control. In the course of developing a program, a determination must be made of the method to be used. If the program is extensive, a combination of methods may be desirable. The principal advantages and disadvantages of each method are:

9.2.1.1 Controlled Burning

This method is the least important in terms of total usage. It is used principally to remove dry vegetation from areas when fire hazards exist due to sparks from locomotive exhausts or braking of trains. This removal of dry vegetation is required by law in some states regardless of the hazards presented. A major objection is atmospheric pollution. Chemical or mechanical control can usually be substituted. But soil erosion may result if the soil is denuded.

9.2.1.2 Mechanical Control

Included in this category are methods involving the use of hand tools, such as brush hooks, axes, and scythes, as well as all types of power equipment since the results obtained are similar. The determination of where to use these mechanical methods should be based on the degree of control desired and existing conditions.

Lawn maintenance by mowing in the vicinity of stations, offices, and other facilities is part of the vegetation control program. Mowing may also be performed on the rights-of-way where terrain permits and particularly in the area beyond drainage ditches to the right-of-way line. It is in this area that ground cover is usually desired. Reasons are:

a. Visibility adjacent to grade crossings.

b. Preventing the spread of weed seed onto adjacent farmlands.

c. Appearance.

The establishment of a permanent, maintenance-free ground cover may be justified. Mowing weeds and grasses in the track and shoulder areas is also useful, principally to cut down uncontrolled vegetation which interferes with the efficient performance of duty by operating and maintenance personnel. The use of this practice in ballasted areas will further contribute to the fouling of ballast.

Recent developments in mechanical control have been largely directed toward brush cutting. Equipment is available to perform this work operating either on-track, off-track, or with the flexibility of rail–highway equipment. On-track equipment has the advantage of not having to operate over rough terrain. The area which can be worked is limited by the lateral reach of the cutting equipment from the track. Productive time may be limited with such equipment, depending upon the density of rail traffic. Off-track equipment can work independently of train movements and is not restricted by the distance from the track. This may be of particular value in working under communication and signal lines. Frequently, the area covered per working hour may be less than with on-track equipment as the equipment has to traverse rough terrain. While rail–highway equipment may be more flexible in many cases by combining advantages of the other two types, its construction is such that it generally cannot cover terrain as rugged as equipment designed exclusively for off-track usage.

The cost of controlling brush by mechanical methods is usually greater than the cost of chemical brush control. Mechanical brush control is appropriate for situations where removal of all standing vegetation is required such as interference with communication lines, clearances, or visibility. Once a knock-down of the brush is accomplished, it will usually be more economical to control regrowth by chemical than by mechanical means. Mechanical control may also be used where the use of herbicides is restricted due to adjacent crops or ornamental vegetation.

9.2.1.3 Chemical Control

The predominate method of controlling vegetation on railroad rights-of-way is with herbicides. Factors which contribute to this widespread usage include:

a. Economy.
b. Ease of application.
c. Ability to regulate degree of control, including percentage of kill, duration of control period, and selectivity.
d. Productivity, which results in less demands on available labor and track occupancy.

9.2.2 DEGREE OF CONTROL

Where controlled burning or mechanical control methods are used, the degree of control obtained is usually a fixed characteristic of the method used. With chemical methods the desired degree of control can be regulated with the area requirements and available funds. It is important to determine the degree of control required by segments in the early stages of planning and develop the program in accordance with these requirements. Degrees of control attainable are described as follows:

9.2.2.1 Bare Ground

Complete elimination of vegetation is the most expensive degree of control. Initial high rates of long residual chemicals followed by reduced rates are required. This is usually desired around timber bridges, switch stands, fuel storage tanks, and other structures and/or areas.

9.2.2.2 Short-Term Weed Control

This term denotes a high degree of vegetation control, but not to the extent that bare ground is obtained. It involves the use of a herbicide or combination of herbicides which produce a quick knock-down plus residual control for less than a growing season. One or two treatments are necessary per growing season, depending on the chemicals used, the problems, and length of the growing season. It may vary as to percent of kill or control desired. This is usually desired in yards and terminals, at highway grade crossings, on passing tracks and sidings, and such main-track areas as ballast sections and shoulders.

9.2.2.3 Chemical Mowing

Non-residual herbicides are used to chemically burn down vegetation. One to four treatments per year may be necessary, depending on rainfall and length of growing season.

9.2.2.4 Selective Weeding

This term denotes the removal of some species of vegetation without damaging the desired species. It has a very limited application on railroad rights-of-way and usually involves the control of such noxious species as bindweed, Johnson grass, brush and marsh cane. This requires the use of specific chemicals.

9.2.3 DETERMINING SCOPE OF WORK

In order to properly determine the scope of work to be accomplished, it is necessary to determine the reasons to control vegetation and the areas where this control is desired. After this is determined, surveys may be conducted to determine the work to be programmed.

9.2.3.1 Reasons to Control Vegetation on Railroad Rights-of-Way

In Ballast Sections:

a. Keep ballast draining properly.
b. Permit proper inspection of track structure.
c. Prevent wheel slippage or sliding.

Shoulders and Ditches:

a. Maintain drainage.
b. Provide safe walkway.
c. Inspection of trains.
d. Reduce fire hazard.

Around Bridges, Buildings and Other Structures:

a. Fire prevention.
b. Permit proper inspection of structure.
c. Facilitate maintenance of structure.

Yards:

a. Safety.
b. Improve efficiency of yard operations.
c. Permit proper inspection of track.
d. Facilitate track maintenance.
e. Fire prevention.

Noxious Weeds:

a. Health and safety of employees.
b. Comply with legal requirements.
c. Reduce spread to neighboring properties.

Signal Appurtenances:

a. To maintain visibility of signals, switch position indicators and derails.
b. To permit safe, efficient operation of switch stands and telephones.

Wayside Signs:

To maintain visibility of speed limit signs, whistle signs, mile posts, etc.

Signal, Communication and Power Lnes:

To prevent service interruptions.

Brush Adjacent to Track:

a. To permit inspection of moving trains.
b. To prevent close clearance hazards.

Highway Grade Crossings:

a. Sight distance for highway and rail traffic.
b. Comply with legal requirements.

9.2.3.2 Surveys

A number of methods may be used to determine the acreages involved in the proposed program. Main-track weed control may be performed on the basis of a fixed pattern involving a constant acreage per mile. This may or may not be supplemented by spot work, the density of which can best be determined by field survey. Areas such as yards may require treatment of the total facility, in which case acreages may be determined from plans. The determination for brush spray requirements usually requires field surveys. Treatment of such facilities as bridge and grade crossings are usually calculated on a unit basis.

The methods of estimating may vary, depending on scope of the work, level at which the estimating is done and degree of familiarity of personnel with actual field conditions. In any case, it is necessary to define the phases of the program contemplated and to determine quantities involved in each phase.

9.2.4 SCHEDULING OF WORK

The type of treatment used may impose limitations upon the season when the work can be progressed. Availability of labor and equipment, climatic conditions and requirements for track occupancy are important considerations.

9.2.4.1 Controlled Burning

This is usually performed in the Autumn after the vegetation has become dry, but before the first snowfall. Rainy weather may severely affect the ability to carry out such a program.

9.2.4.2 Mechanical Control

Weather conditions often affect equipment mobility because of soft ground or snow cover.

9.2.4.3 Chemical Control

To determine herbicides to be used for the control of weeds and grasses, it must first be decided whether pre- or post-emergent applications are desired. Herbicides with a contact or systemic mode of action are of no value in a pre-emergent program. Such an application should be limited to residual-type herbicides. While residuals are also of considerable value in post-emergent applications, they are normally used in combination with contact and/or systemic materials in such programs. Factors such as prevalence of rainfall and length of growing season may also be of significance in the determination of treatment schedules.

There are several chemical brush control treatments that may be used in a program:

9.2.4.3.1 Summer Foliage

Such treatments are made after the brush reaches full leaf but while the brush is still growing actively.

9.2.4.3.2 Dormant Stem (Cane)

Such applications are made during late Fall and Winter while the brush is completely dormant. An advantage of this method is the elimination of potential damage to adjacent crop lands that can be caused by drift in summer foliage applications.

9.2.4.3.3 Basal Treatments

These are generally individual stem treatments. This method can be used any time of the year. The herbicide is directed to the basal area or stump and to the root collar area. It is of particular value for control of cut stumps or for clean up of scattered plants.

9.2.4.3.4 Soil Applications

Such applications are made by the use of pellets and liquids either by broadcasting or by spot application on the ground around individual stems or clumps. This type of application can be made at any time of the year except when the ground is frozen. Also, rainfall is necessary to activate these materials.

9.2.5 CHEMICAL CONTROL—SELECTION OF HERBICIDES

9.2.5.1 Species to Be Controlled

An important consideration in herbicide selection is the kind of vegetation to be controlled. Generally, vegetation is categorized as grasses, broad-leafed weeds, vines or brush. Programming around such broad categories can frequently be beneficial in that it will lead to the selection of herbicides that are reasonably effective on many species which are included in the predominant category. There is considerable variation in susceptibility of different speces to herbicides.

Species resistant to the treatment being used become better established from continued use of the treatment as the susceptible species are eliminated.

9.2.5.2 Determining Suitable Herbicides

Table 1 identifies many of the commonly used herbicides together with pertinent information. Many of the herbicides presently in use have been developed within the past few years. The future will likely bring continued development of herbicides. Personnel charged with vegetation management should keep abreast of new developments.

A reliable source of data pertinent to a particular herbicide is the label which is affixed to the herbicide container, and the literature which is used in promoting the product. Literature is now considered to be a part of the official label by the Environmental Protection Agency.

All labels require approval by EPA and must show the registration number of EPA (usually at bottom of center panel on label) to be official. Herbicides cannot be traveled either intra or interstate without this official label.

The Insecticide, Fungicide and Rodenticide Act, as amended (Federal Environmental Pest Contral Act of 1972) requires exhaustive investigation and testing prior to granting of label approval. Many government agencies are involved, such as the Food & Drug Administration, Public Health, Fish & Wildlife Service, Department of Agriculture, and finally the EPA.

In addition to performance data from all over the country, extensive toxicity tests must be run before a herbicide label can be granted.

Climate and soil conditions affect the effectiveness of a herbicide. Therefore, regional information published by state and federal agencies are often of value in vegetation management decisions.

9.2.5.3 Other Considerations

Prior to finalization of the choice of herbicides, a number of other factors should be considered which might have an effect on their performance under specific conditions. Significant factors are:

9.2.5.3.1 Soil Type

Soils are complex and vary considerably from one area to another due to their composition. The basic materials from which soils are composed are: sand, clays, silt, organic matter, and various minerals. The nature of and number of these individual particles, to a large degree, determines what happens to a herbicide applied to a soil.

9.2.5.3.1.1 Sand has very little ability to hold water or chemicals. Chemicals will leach readily in soils that are high in sand.

9.2.5.3.1.2 Clay soils are generally more impervious to water and chemicals, and, because of the small size and high number of particles, can tie up a sizeable percentage of herbicide by absorption. Clays vary in their absorption characteristics; for instance, clays of the Midwest may be as much as three times more absorptive than clays in the South and Southwest.

9.2.5.3.1.3 Silt is comparable to sand in its absorptive properties.

9.2.5.3.1.4 Organic content is important to characteristics of a soil. It is similar to clay in its ability to tie up chemicals. It is also a medium for microscopic life, many chemicals being attacked and broken down by soil microbes. If a chemical is subject to microbial breakdown its life in organic soils is usually shortened.

9.2.5.3.2 Rainfall

Rainfall is a primary factor in determining the herbicide to be used. The amount of water to a high degree determines the types of plants that will grow in a specific area. It is also necessary to activate residual herbicides.

During drought periods, plants usually undergo growth stress conditions, causing most translocated chemicals to perform poorly. Contact-type chemicals usually do not perform well under drought conditions as the plants produce heavy, wax or corky layers of tissue on leaves or stems to protect against excessive transpiration losses. During dry periods herbicides remain on the soil surface until moisture is received to dissolve and carry it into the root zone. Low solubility compounds are usually used in heavy rainfall areas and higher solubility compounds in arid or semiarid regions.

9.2.5.3.3 Length of Growing Season

Along with soil type and rainfall, length of growing season is an important factor in selecting the proper herbicide. Normally, the longer the growing season the more resistant is the vegetation. This necessitates higher rates to realize a given degree of control. Also, the combination of long growing season and high rainfall results in the leaching of residual chemicals below the root zone, requiring multiple applications.

9.2.5.3.4 Toxicity

Relative toxicity may be a factor in the selection of the herbicide to be used. Both oral and dermal toxicities of herbicides are listed in Table 1. The LD-50 system of rating oral toxicity is explained in Table 2.

9.2.5.3.5 Governmental Regulation

The Federal Environmental Pest Control Act provides guidelines and authority for regulating and enforcing the proper use of herbicides.

Railroads engaged in vegetation control programs, whether contractor or self-applied, should be sure that proper licensing in the states where applications are to be made has been obtained. Consult the State Pesticide Control office—(usually at the state university) for proper licensing procedure.

9.2.5.4 Selection of Herbicide

These variables point out that there is no ideal herbicide for all applications. There may be two or more materials of comparable suitability. At this point, relative economy may be the decisive factor. Even the most economical herbicide (or combination) may cost more than funds available. In such a situation a review of the desired degree of control may be in order. If the original proposals are to be adhered to, then low-priority items should be eliminated from the program rather than apply an insufficient dosage over the entire territory.

9.2.6 SELECTION OF EQUIPMENT

9.2.6.1 Controlled Burning

Principal equipment consists of on-track weed burners and hand-carried torches utilizing various petroleum products. Where this method is used, it is important to provide adequate protective equipment (such as mobile water tanks).

9.2.6.2 Mechanical Control

9.2.6.2.1 Weeds and Grasses

Both on-track and off-track equipment is available. On-track equipment is limited in lateral reach. Both sickle-bar and rotary-type equipment is available.

9.2.6.2.2 Brush

Equipment is generally of the rotary type. On-track, off-track and highway–railway equipment is available. On-track and highway–railway equipment is available with varying lateral reaches and may be of the single- or double-arm type. Off-track equipment may be rubber-tired or caterpillar type and cutters may be either underslung or towed. Manually operated equipment consists of either chain saws or rotary saws. It is suitable for terrain inaccessible to heavy equipment and for spot removal of large trees.

9.2.6.3 Chemical Control

9.2.6.3.1 Spray Trains

Such equipment is capable of transporting large quantities of herbicide and diluents. Daily productivity is high on long runs. It loses much of its efficiency in terminal areas and on short branches. Multi-treatment capabilities are also possible. Require use of an engine and operating personnel.

9.2.6.3.2 Highway–Railway Trucks

Principal limitation is the tank capacity, 1000 to 2000 gal. The trend to lower volumes is increasing the capability of this equipment. They are mobile and require fewer personnel to operate them than spray trains.

9.2.6.3.3 Dry Material Spreaders

They are capable of dispensing granular and pelletized materials, and units are available as wheelbarrow hand spreader and powered types. They are of particular value in reaching areas not readily accessible to spray equipment. Calibration is generally less accurate than with spray equipment.

9.3 EXECUTING A VEGETATION CONTROL PROGRAM

9.3.1 PROGRESS REPORTS

Accurate records can serve a number of purposes.
Some of them are:

a. Day-to-day policing of progress of work and material usage. Information furnished may justify modifications in the program.
b. Provide the means for developing actual costs. Knowledge gained may serve as the basis for changes in future programs.
c. Provide data on actual productivity. Can be valuable in planning schedules for future programs.
d. May provide evidence needed in case of claimed damage.

When establishing a record-keeping system the following guidelines may be considered:

a. Determine purposes for which records are intended and design forms to conform to these purposes. Don't collect data that will never be used.
b. Determine whether it is practicable to obtain the information desired.
c. If a contract operation is involved, determine information that contractor will provide and whether it meets railroad's requirements.
d. It is necessary that daily records be transmitted promptly to all involved personnel.

9.3.2 TECHNIQUES OF CHEMICAL CONTROL

9.3.2.1

Herbicides are available in various preparations. Field personnel should be familiar with these formulations and their requirements, prior to the start of application. The formulations in general use are:

9.3.2.1.1 Sprays

a. Water solutions—Completely soluble in water.
b. Emulsions—A mixture in which small droplets of one liquid are suspended in another. A water-in-oil emulsion is known as an invert emulsion.
c. Wettable powders—Powders that readily suspend in water.
d. Soluble powder—A powder that dissolves completely in water.

9.3.2.1.2 Formulations for Dry Applications

a. Granules—A carrier for the herbicide.
b. Pellets—A homogeneous formulation of a herbicide.

9.3.2.2

9.3.2.2.1 Mixing and Agitation

Most solutions applied for weed control are prepared in the field. Concentrate chemicals are diluted to prepare and maintain homogeneous mixtures for application with calibrated equipment.

9.3.2.2.2 Calibration

To insure the proper rate of applications of the prescribed chemicals, a calibrated meter must be included in the system and the following must be taken into account:

(a) Number of outlets
(b) Size and capacity of nozzles (orifice size)

(c) Dilution ratio of chemicals

(d) Operating pressure

(e) Speed of application equipment

A check of the proper calibration should be made before initial operation begins and re-checked daily to assure continuity of the proper rates of application of the chemicals.

9.3.2.2.3 Speed and Pressure Control

Speedometers and pressure gages should be integral parts of any application equipment. A change of speed will disrupt the calibrated dosage of chemicals unless the operating pressure is also changed at the same time, i.e., an increase in speed will reduce the dosage of materials and, thus, the operating pressure must be increased to offset this difference.

9.3.2.2.4 Clogging of System

Clogging, or any obstruction in the spraying system, is detrimental to good vegetation control practices. To counteract this possibility, strainer units are placed in the system, preferably ahead of the intake side of the pump. In some cases, strainers are provided in the head of the nozzle.

Clogging can be caused by:

(a) Accumulation of rust from distributing containers and chemical pipe lines.

(b) Silt, sticks and stones from water sources.

(c) Precipitation of chemicals caused by improper mixing techniques.

(d) Accumulation of improperly agitated, unsoluble residuals in the chemical pipe line and/or pump volute.

9.3.3 PRECAUTIONS

9.3.3.1 Burning

Control of vegetation by burning introduces a number of hazards. Before burning is undertaken sufficient protection should be on hand to prevent the spread of fires to adjacent property. Burning should be avoided in the vicinity of wood bridges and other structures. A less obvious but potentially serious hazard is the possibility of fires becoming established underground in cinders, peat and wood chips, which may go undetected until well established. They can be difficult to extinguish and may result in collapse of the roadbed.

Air pollution caused by burning is of increasing concern and is sometimes prohibited by law.

9.3.3.2 Mechanical Control

In the selection of equipment for a particular job, consideration should be given to its suitability for the use contemplated. Some of the more common safety hazards are:

a. Overturning on slopes.

b. Flying objects from cutting blades.

c. Presence of stone, scrap, cable, wire, etc.

d. Stumps and stubble.

e. Hand tools (chain saws, etc.)—exposure to cutting edges.

f. Danger of falls during manual work on steep slopes.

9.3.3.3 Chemical

When applying vegetation control chemicals, the possibility of wind causing drift of the spray mix materials should be considered. Spray drift can cause damage to susceptible crops and ornamentals that are adjacent to the right-of-way and may result in litigation. Application should immediately cease if the herbicide cannot be confined to the target area.

Individual state statutes should be considered regarding wind velocity.

Application techniques, mechanical devices and/or drift control agents may be utilized to control drift.

Rain can be both beneficial and harmful. Rain does provide the moisture necessary to maintain the plants in an active, growing state, which permits the uptake of the applied herbicides and to carry residual chemicals to the root section of the plants.

On the other hand, rain immediately after treatment can wash the chemical from the plants (as in the case of contact herbicides) and/or cause run-off of the chemicals out of the target site.

9.4 EVALUATING RESULTS OF A VEGETATION CONTROL PROGRAM

9.4.1 FIELD INSPECTIONS

9.4.1.1 Controlled Burning

The principal field evaluation of a controlled burning program is to determine the extent to which the programmed territory was covered and to identify any damage resulting from such a program. As the results of such a program are of relatively short duration, such an evaluation should be made fairly soon after the burning is accomplished.

9.4.1.2 Mechanical Control

Field evaluation of mowing of weeds and grasses can determine whether the frequency of such operations is consistent with the results desired and the degree of effectiveness of such procedures on the terrain involved. Brush-cutting operations should be evaluated on the basis of rate of regrowth and increased brush density due to suckering.

9.4.1.3 Chemical Control

9.4.1.3.1 Rating Extent of Control Obtained

9.4.1.3.1.1 Brush control—Inspection at the end of the first growing season should be made to determine whether coverage is uniform throughout the target area. All brush should show typical herbicide response. Brush height and density may necessitate spraying in two consecutive years in order to obtain effective control of all brush when using on-track spray equipment. Final evaluation should be made at the end of the second growing season following application of the herbicide. At this time it can be determined if degree of control is consistent with requirements.

9.4.1.3.1.2 Weeds and Grasses—Evaluation should be made near the end of the growing season in which the treatment is made but prior to the first frost. Rating should be on the basis of percentage of effectiveness.

9.4.1.3.2 Identifying Problem Species

It is possible that any remaining vegetation will consist of a limited number of species which are resistant to the treatment used. Even if such species represent a small problem at the time of inspection, it is likely that they may proliferate due to the elimination of competing species. Future programs should be designed to control these remaining species.

9.4.1.3.3 Relating Results to Original Goals

The results of a spray program should be consistent with the needs as described in sections 9.2.2 and 9.2.3.1. Having pictures of representative areas taken prior to the application of herbicides can be a valuable aid in making evaluations. Such pictures should be identified as to location and date.

9.4.1.3.4

If it is determined that results are not consistent with what might reasonably be expected, one or any combination of the following may be contributing factors.

9.4.1.3.4.1 Chemicals

a. Improper mixing procedures.

b. Incompatibility between herbicides and/or their carriers.

9.4.1.3.4.2 Weather

a. Rain too soon after application can wash the herbicide from the plant or the soil surface.

b. Heavier than normal rainfall can leach and dilute soil applied herbicides.

c. Rainfall may be inadequate to activate soil-applied herbicides.

d. Wet brush will not accept oil carrier spray solutions.

e. Extended periods of dry weather also reduce the effectiveness of foliar applied herbicides.

9.4.1.3.4.3 Equipment

a. Improper calibration.

b. Inadequate agitation.

c. Clogging of nozzles.

9.4.2 ECONOMIC ANALYSIS

In addition to costs of material and contracts, labor and equipment costs can be a significant part of the total cost of vegetation control. Labor and equipment unit costs will vary with productivity. Well designed and properly completed daily reports can be an invaluable tool in determining such costs and evaluating the efficiency of the operation.

Thorough analysis of such reports may indicate that changes should be considered in future programs in factors such as scheduling, type of equipment used, co-ordination with train operations, personnel assigned and type of treatment.

TABLE 1—TYPES AND CHARACTERISTICS OF HERBICIDES

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD_{50}	Dermal		Pre-Emergence	Post Emergence	
I. SELECTIVE HERBICIDES									
A. Broadleaf Control Herbicides									
1. Phenoxy Compounds a. 2,4-D Amine 2, 4 dichlorophenoxy acetic acid.	Commonly sold as 4 lb. per gallon acid equivalent. True solution. Also available as oil soluble amine.	Foliage absorbed & translocated increases respiration.	Slightly soluble in water (605 ppm) non-corrosive and non-flammable. Short-lived in soil (2 to 4 weeks). Should be sequestered against 800 ppm hardness of water.	500 Slightly toxic Class 4	Mildly irritating Class 4	Avoid drift to susceptible crops & other valuable broadleaf plants.	Not recommended	2-4 lb. higher rates required to control certain resistant species.	Controls most broadleafed weeds. Certain perennial weeds & vines. Performs best when plants are growing rapidly.
b. 2,4-D Ester 2,4 dichlorophenoxy acetic acid.	Commonly sold as 4 lb. acid equivalent per gal. Used in oil/water emulsion.	As above.	Emulsifiable in water. Compounds may be volatile at temperatures above 110°F. Non-flammable.	500 Slightly toxic Class 4	Mildly irritating Class 4	As above. High volatile esters such as ethyl, methyl or butyl not recommended	Not recommended	As above.	More effective than amines on hard-to-kill broadleafed weeds. May be used in water, oil/water or straight oil carriers.
c. 2,4,5-T Amine Trichlorophenoxy acetic acid.	Commonly sold as 4 lb. acid equivalent per gal. True solution.	As above.	Slightly soluble in water. (238 ppm) Other properties similar to 2,4-D. May precipitate in water at 400-500 ppm hardness if unsequestered.	300 Moderately toxic Class 3	Mildly irritating Class 4	Same as 2, 4-D Amine.	Not recommended	4-8 lb/100 gal. for woody plants. Volume determined by height and density.	Non-volatile. Controls many broadleaf weeds, vines & woody plants. Used primarily as a brush killer. Not as effective as 2,4,5-T Ester for aerial application or late in season-ground application.

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD_{50}	Dermal		Pre-Emergence	Post Emergence	
d. 2,4,5-T low volatile Ester.	Commonly sold as 4 lb. per gal. acid equivalent. Used in oil/water emulsion.	Foliage absorbed & translocated increases respiration.	Slightly soluble in water (238 ppm) Other properties similar to 2,4-D.	300 Moderately toxic. Class 3	Mildly irritating Class 4	Same as 2,4-D Ester.	Not recommended	4-8 lb/100 gal for woody plants. Volume determined by height & density.	May be used in water, oil/water or straight oil carrier. Used primarily for brush control. Used alone or in combination with 2,4-D Ester.
e. 2,4-D/2,4,5-T Amines.	Commonly sold as 2 lb. of 2,4-D and 2 lb. of 2,4,5-T acid equivalent per gal. Oil and water soluble amines marketed.	As above.	Same as for 2,4-D Amine.	300-500 Moderately toxic. Class 3	Mildly irritating Class 4	Same as 2,4-D and 2,4,5-T Amine	Not recommended	As above.	Controls many broadleafed weeds, vines & woody plants. Sold primarily as a brush killer. Oil soluble formulations preferred under arid conditions
f. 2,4-D/2,4,5-T low volatile Ester	Commonly sold as 2 lb. of 2,4-D and 2 lb. of 2,4,5-T acid equivalent per gal.	Foliage absorbed & translocated increases respiration.	Same as for 2,4-D Esters.	300-500 Moderately toxic. Class 3	Mildly irritating Class 4	Same as for 2,4-D and 2,4,5-T LV Ester.	Not recommended	2-3 gal/100 gal solution as a foliage spray. 3-4 gal/100 gal oil for basal or dormant cane spray.	Same as 2,4,5-T Ester.

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD_{50}	Dermal		Pre-Emergence	Post Emergence	
2. Amitrol (Amino-1,2,4 Triazole)	Fine, white to grayish water soluble powder (90% active)	Foliage translocated inhibits formation of chlorophyl.	Very soluble in water. Decomposes in 7 to 14 days in the soil	2,500 Slightly toxic Class 4	Mildly irritating Class 4	None	Not Used	2-4 lb. on annuals. 4-10 lb. on perennials. Apply to rapidly growing vegetation.	Used primarily to control perennial weeds & grasses. Useful in combination with other herbicides.
3. TBA (2,3,6 Trichlorobenzoic acid).	Sold as 2 lb. acid equivalent per gal. True solution. Dry formulation also available:	Primarily root absorbed.	Very soluble in water. Non-flammable. Has soil residual.	1,640 Slightly toxic Class 4	Mildly irritating Class 4	Spray drift may injure susceptible crops.	4 lb. on broadleafed annuals.	5-10 lb. on woody vines & many perennial broadleafed plants. Up to 20 lb. required on many noxious weeds. 4 lb. per 100 gal. of water used on brush.	Used primarily to control perennial weeds & vines. Generally used in combination with other herbicides.
4. Fenac (2,3-6 trichlorophenylacetic acid).	1½ lb. active per gal. True solution of sodium salt.	Primarily root absorbed.	Very soluble in water (200,000 ppm). Non-flammable. Has soil residual.	3,000 Slightly toxic. Class 4	Mildly irritating Class 4	Spray drift may injure susceptible crops.	4 lb. on broadleafed annuals.	4.5 to 6 lb. on woody vines & many perennial broadleaf plants, when used in combination with other herbicides. Up to 18 lb. required on many noxious perennials. Not recommended for brush control.	

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD_{50}	Dermal		Pre-Emergence	Post Emergence	
5. Dicamba	Sold as 4 lb. gal. True solution. Also combinations with various phenoxys.	Foliage translocated and root absorbed.	Non-flammable, slightly corrosive, solubility is .45 grams active ingredient per 100 ml.	2,900 Slightly toxic. Class 4	Mildly irritating. Class 4	Spray drift may injure susceptible crops.	Not recommended.	½ lb. Dicamba plus 1 to 2 lb. 2,4-D for broadleaf weeds & vines. 1 lb. Dicamba plus 2 lb. 2,4-D or 2,4,5-T for woody plants.	Used to control perennial weeds, vines & woody plants as foliage applications. Is often used in combination with residual herbicides.
6. Picloram	True solution; Several formulations sold with 2,4-D & 2,4,5-T; also as beads (dry) and 10% pellet.	Foliage absorbed & translocated when applied as spray, root pick up in dry forms.	430 PPM solubility in water.	8,200 Almost non-toxic. Class 5	Mildly irritating. Class 4	Spray drift may injure susceptible crops.	Not used pre-emergence on weeds	.25 to .5 on broadleafed weeds, 1-3 lb. on perennial vines & 2 to 4 lb. on brush. Use above or with 2,4-D & 2,4,5-T.	Used for broadleafed weeds, perennial vines and brush.

B. Systemic Grass Control Herbicides

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	LD_{50}	Dermal	Use Precautions	Pre-Emergence	Post Emergence	Other Pertinent Information
1. Dalapon (2,2-dichloropropionic acid).	Sold as 85% soluble salt. Also as true solution 4 lb. gal. in tank cars.	Foliage and root absorbed.	Very soluble in water (310,000 ppm). Slightly corrosive to metals. Hygroscopic. Non-volatile. Soil residual 20 to 40 days.	9,300 Almost non-toxic. Class 5	Moderately irritating. Class 3	Chemical breaks down in temperature above 80°F.	Not Used	15 to 25 lbs. plus ½% surfactant. Good on grasses only.	Best results obtained when applied during warm, moist periods to rapidly growing grasses. Generally used in combination with other herbicides.

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD $_{50}$	Dermal		Pre-Emergence	Post Emergence	
2. TCA (Sodium salt of trichlorocetic acid).	90-94% soluble crystalline material. Also 6 lb./gal. solution.	Primarily root absorbed.	Very soluble in water (545,000 ppm). Hygroscopic. Corrosive to metals. Non-flammable. Non-volatile. Soil residual of 21 to 70 days.	5,000 Almost non-toxic. Class 5	Causes burns and blisters. Class 2		Not recommended	60-120 lbs. plus ¼% surfactant by volume.	Best results obtained when applied during warm, moist periods to rapidly growing grasses. Generally used in combination with other herbicides.

II. NON-SELECTIVE HERBICIDES

A. Contact Herbicides

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD $_{50}$	Dermal		Pre-Emergence	Post Emergence	
1. Ammonium Sulfamate	Soluble crystalline salt containing 95% ammonium sulfamate & as a solution containing 5.6 lb. active ingredient per gal. in tank cars.	Acts as contact and translocated herbicide.	Moderately soluble in water (2,900 ppm). Non-flammable, non-volatile, corrosive to ferrous metals and brass but not to stainless steel and aluminum.	3,900 Slightly toxic. Class 4	Non-irritating Class 5	None	Not Used.	60 lb/100 gals plus ¼% surfactant by volume or plus 4 gals. No. 2 diesel oil plus 2/3 pt emulsifying agent. Volume per acre determined by height & density of brush.	On railroads used for brush control. May be safely applied close to valuable vegetation because of freedom from volatility.
2. Cacodylic Acid	True solution containing 3.25 lb. per gal.	Contact foliage absorption.	Very soluble in water. Works best on warm sunny days (temp. above 60°F.)	830 Slightly toxic. Class 4	Mildly irritating. Class 4	Use with surfactant and on warm days.	Not Used.	1-1/2 gal. per acre (4.8 lb).	Use as contact herbicide.

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD_{50}	Dermal		Pre-Emergence	Post Emergence	
3. Monosodium Methane Arsonate (MSMA). Often expressed as DSMA hexadrate equivalent.	Marketed as true solution of varying concentration per gal.	Contact foliage absorption.	Very soluble in water. (405,000 ppm); work best when temperatures are above 75°F. Surfactant required.	700 Slightly toxic. Class 4	Mildly irritating Class 4	Do not use at temperatures below 75°F. or without surfactant.	Not used	4-6.6 lb. plus ¼% surfactant by volume (8-12 lb. DSMA equivalent).	Used as contact herbicide in combination with residual herbicide.
4. Paraquat	True solution containing 2 lb. per gal.	Contact foliage absorption.	Very soluble in water. Works at most operating temperatures.	150 Moderately toxic. Class 3	Moderately irritating Class 3	Do not inhale. Keep off skin & clothes. Keep out of eyes; may be fatal if swallowed	Not used	1 qt. on seedlings and annuals. 2 qt. on tough perennials.	Broad spectrum contact herbicide.
5.. Sodium Chlorate	90% salt with fire retardant such as sodium metaborate or calcium chloride. Sold as custom solutions, granulars & pellets alone or in combination with other herbicides.	Inhibits photo-synthesis. Good contact action.	White crystalline salt. Very soluble in water (410,000) ppm corrosive to spray equivalent. Flammable when with organic matter & allowed to dry.	5,000 Almost non-toxic. Class 5	Mildly irritating. Class 4	Must be used with proper fire retardant.	Not recommended.	100-200 lb. alone or in combination with other herbicides	Broad spectrum contact herbicide.
6. Weed Oils	True solutions vary widely in aromatic content.	Contact foliage absorption.	May be flammable		May burn skin.	Keep off skin & clothes. Keep off automobiles	Not used.	40-100 gal. per acre.	

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD_{50}	Dermal		Pre-Emergence	Post Emergence	
				8. Long Residual Herbicides					
1. Substituted Uracils—Bromacil	80% wettable powder 2 lb./gal. true liquid. Granular or pelletized formulations available for dry application. Custom solution also available.	Some contact when applied with surfactants. Primarily root absorbed. Inhibits photosynthesis.	Slightly soluble in water (815 ppm) non-volatile. Non-corrosive.	5,200 Almost non-toxic Class 5	Mildly irritating Class 4	Very toxic to roots of valuable trees.	2-5 lb. for seedling control. 20 lb. for bare grounds.	2-5 lb. for seedling control plus ½% surfactant by volume. 10-20 lb. plus surfactant for bare ground.	Often used in combination with other herbicides. Used for brush control at 7½ lb. to 15 lb. applied to soil.
2. Substituted Triazines a. Atrazine	80% wettable powder	Requires moisture to dissolve & is root absorbed; inhibits photosynthesis causing chlorosis & plant starvation.	Very slightly soluble in water. Non-flammable. Non-corrosive. (70 ppm)	3,080 Slightly toxic. Class 4	Non-irritating Class 5	Do not apply to root system of valuable plants at bare ground rates	3-8 lb. seedlings; 20-50 lb. for bare ground.	10-50 lb. used alone or in combination with systemic or contact herbicides.	
b. Simazine	80% wettable powder	As above.	As above except 8 ppm solubility	5,000 Almost non-toxic Class 5	Non-irritating Class 5	As above.	As above.	As above.	
c. Prometone	2.5 lb./gal. water or oil soluble formulation; 5% pelletized product for dry application; also customized formulation with penta, oil & 2,4-D.	Requires moisture to dissolve & is root absorbed; inhibits photosynthesis causing chlorosis & plant starvation.	750 ppm solubility in water. Non-corrosive. Non-volatile.	2,980 Slightly toxic. Class 4	Mildly irritating Class 4	Do not apply to root systems of valuable plants	5-10 lb. for seedlings.	10-60 lb. used alone or in combination with systemic or contact herbicides.	

TABLE 1 (CONTINUED)

Chemical	Formulations Marketed	Mode of Action	Chemical and Physical Properties	Toxicology		Use Precautions	Use Rates, Active Ingredients Per Acre		Other Pertinent Information
				LD$_{50}$	Dermal		Pre-Emergence	Post Emergence	
3. Substituted Ureas a. Diuron	80% wettable powder granular or pelletized formulations available for dry application.	Requires moisture to dissolve & is root absorbed. Inhibits photosynthesis causing chlorosis & plant starvation.	Very slightly soluble in water (40 ppm).	3,400 Slightly toxic. Class 4	Mildly irritating Class 4	Do not apply to root systems of valuable plants.	3 to 8 lbs. for control of seedlings; 20-50 lb. bare ground.	8-50 lbs. used in combination with systemic or contact herbicides.	
b. Monuron	As above.	As above.	Slightly soluble in water (240 ppm) non-flammable, non-volatile, non-corrosive.	3,600 Slightly toxic. Class 4	Non-irritating Class 5	Do not apply to root system of valuable plants at bare ground rate.	5 to 8 lbs. for control of seedlings; 20 to 50 lbs. for bare ground.	8 to 50 lbs. used in combination with systemic or contact herbicides.	
4. Urea Carbonates Karbitulate.	80% wettable powder, 10% granules, 4% granules.	Requires moisture to dissolve & is root absorbed. Inhibits photosynthesis causing chlorosis & plant starvation.	Slightly soluble in water (325 ppm) non-flammable, non-volatile, non-corrosive.	3,000 Slightly toxic. Class 4	Mildly irritating Class 4	Do not apply to root system of valuable plants at bare ground rate.	2-5 for control of seedlings; 10-20 lb. on perennials.	2-5 for control of seedlings; 10-20 lb. on perennials.	

For additional information, refer to the Weed Science Society of America Herbicide Handbook.

TABLE 2 - HERBICIDE TOXICITY RATINGS

ORAL TOXICITY

Toxicity* Rating	Class	Signal Word	LD_{50} (mg./kg.)	Probable Lethal Dose
1	Extremely toxic	Danger - Poison	Less than 5	A taste (less than 7 drops)
2	Very toxic	Danger - Poison	5 to 49	7 drops to 1 tsp.
3	Moderately toxic	Warning	50 to 499	1 tsp. to 1 ounce
4	Slightly toxic	Caution	500 to 4,999	1 ounce to 1 pint (1 lb.)
5	Almost non-toxic	None	5,000 to 14,999	1 pint to 1 quart

DERMAL TOXICITY

Toxicity Rating	Classification
1	Absorbed and poisonous
2	Causes burns and blisters
3	Moderately irritating
4	Mildly irritating
5	Non-irritating

A. LD_{50} (a measurement of toxicity) is the amount of material to be lethal to 50% of the number of animals in the experiment. It is stated in milligrams of material to kilograms of body weight: 1 pound = 454 grams; 1 kilogram = 1,000 grams; 1 gram = 1,000 milograms.

B. The LD_{50} is applicable whether the chemical enters the body by inhalation, adsorption through the skin or swallowed by mouth.

C. Generally, the LD_{50} value for a material ingested via the respiratory route is lower than the oral LD_{50} and the LD_{50} by the dermal route is higher.

D. "Lethal dose for 150-pound man" is based on table in Clinical Toxicology of Commercial Products by Gleason, M.N.; Gosselin, R.E.; and Hodge, H.E.; Williams and Wilkins Co., Baltimore, Maryland, 1957.

* - From:
USDA
Agriculture Handbook No. 332-1969

Manual Recommendations

Committee 6—Buildings

Report on Assignment B

Revision of Manual

T. H. Seep *(chairman, subcommittee),* F. R. Bartlett, K. E. Hornung, J. G. Robertson, S. G. Urban.

Your committee submits for adoption the following recommendations with respect to Chapter 6 of the Manual:

PART 2—DESIGN CRITERIA FOR RAILWAY OFFICE BUILDINGS

Add on page 6.2.7 the following new Article, including Fig. 4, to Section 2.4 Spacial Requirements:

2.4.7 Conference Rooms

(a) The size of the room and the size of the conference table is directly related to the number of persons to be seated. (See Fig. 4). Room sizes shown are minimum room dimensions.

(b) Conference tables may be rectangular, round, boat-shaped or oval. Table width should increase as the number at the table increases.

(c) Allow 30 in per person for chair space to permit comfortable spacing at the conference table.

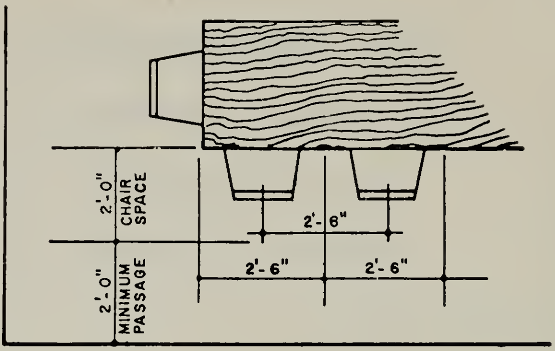
(d) Adequate doors must be provided for ease of entry and exit.

1. Up to 24 persons—1 door.
2. More than 24 persons—2 doors.

(e) A hard-surface ceiling over the conference table is desirable in large rooms (16 persons and over) to reinforce voice travel. Floors should be carpeted to minimize background noise.

(f) Consideration should be given to the incorporation of any of the following special features as required.

1. Coat racks or closet
2. Projection booth
3. Toilet facilities
4. Kitchenette
5. Sound and/or Video systems
6. Built in bulletin and chalk boards
7. Special ventilation
8. Draperies and room darkening equipment



NUMBER OF PEOPLE	TABLE		ROOM	
	LENGTH	WIDTH	LENGTH	WIDTH
4	5'-0"	2'-6"	12'-0"	10'-0"
6	6'-0"	2'-6"	14'-0"	10'-0"
8	8'-0"	2'-6"	16'-0"	12'-0"
10	10'-0"	3'-0"	20'-0"	14'-0"
12	12'-0"	3'-0"	22'-0"	14'-0"
14	15'-0"	3'-0"	25'-0"	15'-0"
16	18'-0"	3'-6"	30'-0"	16'-0"
18	20'-0"	3'-6"	32'-0"	16'-0"
20	22'-0"	3'-6"	35'-0"	17'-0"
ROUND TABLES				
4	2'-8" dia.		10'-0"	10'-0"
6	4'-0" dia.		12'-0"	12'-0"
8	5'-4" dia.		14'-0"	14'-0"
10	6'-8" dia.		16'-0"	16'-0"

Space Requirements For Conference Rooms

Fig. 4

Your committee also recommends the deletion from Chapter 6 of Parts 20—Stations, 23—Locomotive Sanding Stations, 25—Shops, 26—Miscellaneous Buildings, and 27—Insurance; and the adoption of the following new material:

Part 6

Locomotive Sanding Facilities

6.1 GENERAL

6.1.1 Types

(a) Predried sand. This sand is delivered to the servicing station, dried at some central drying plant or purchased from a sand plant.

(b) Green sand is delivered in bulk form to the servicing station and must be dried before it can be used as engine sand.

(c) Waste from granite quarries should be considered as a source of engine sand.

(d) Design. The type of sand used will dictate, to a point, the type of sand facility to be installed.

6.2 CAPACITY

6.2.1 The sand requirement at a location is an important factor affecting storage capacity. Availability of the material should be considered in determining storage capacity.

6.2.2 In green sand storage plants, wet sand should be placed in storage during the summer months in amounts sufficient to carry through freezing weather, thus avoiding the results of freezing conditions.

6.2.3 Dry sand storage plants, even with sand readily available, should preferably have a capacity in excess of one carload.

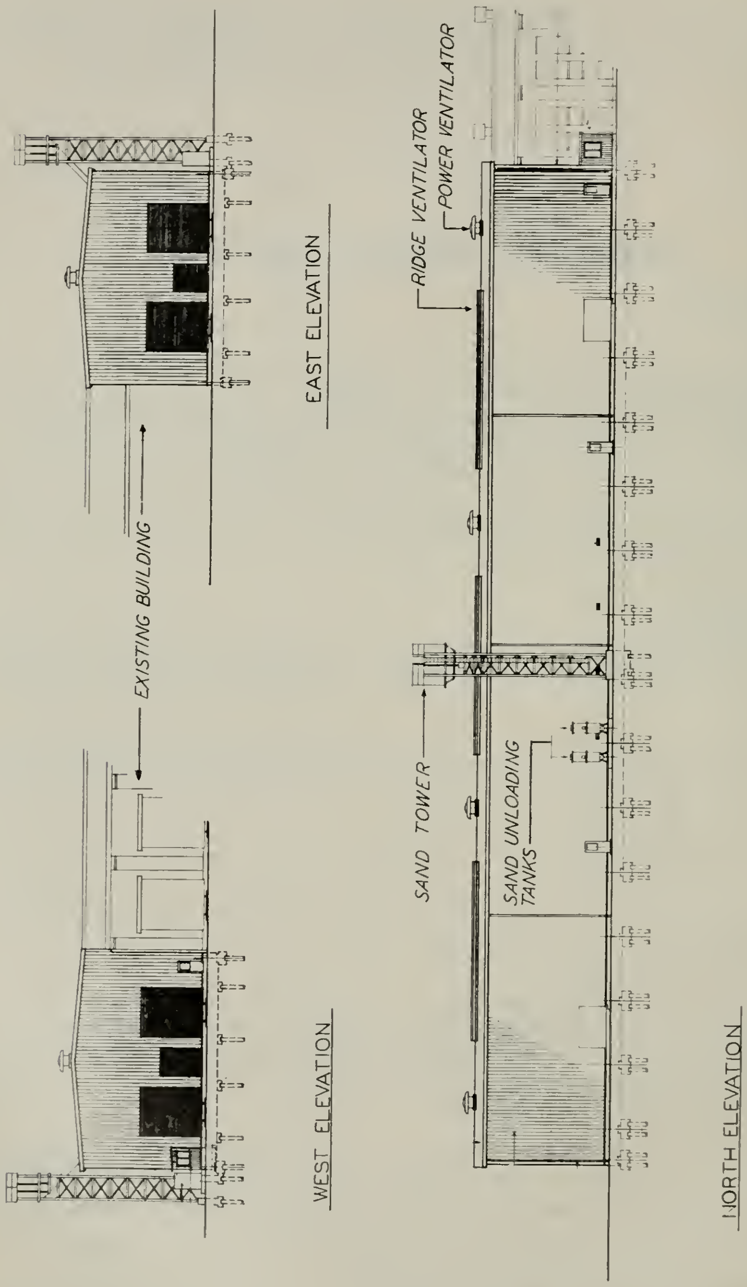
6.2.4 In outlying sections where the demand is light, it may be found desirable to provide a bin with a capacity of less than a carload, so that a carload of sand can be distributed among several locations.

6.2.5 Carrying bulk dry sand in storage in too large quantities is not recommended where the turnover is slow and the humidity is high, as condensation is a factor. The sand under such conditions tends to take up moisture, resulting in an unsatisfactory condition for flowing. Where there is a quick turnover of sand the absorption of moisture is not serious.

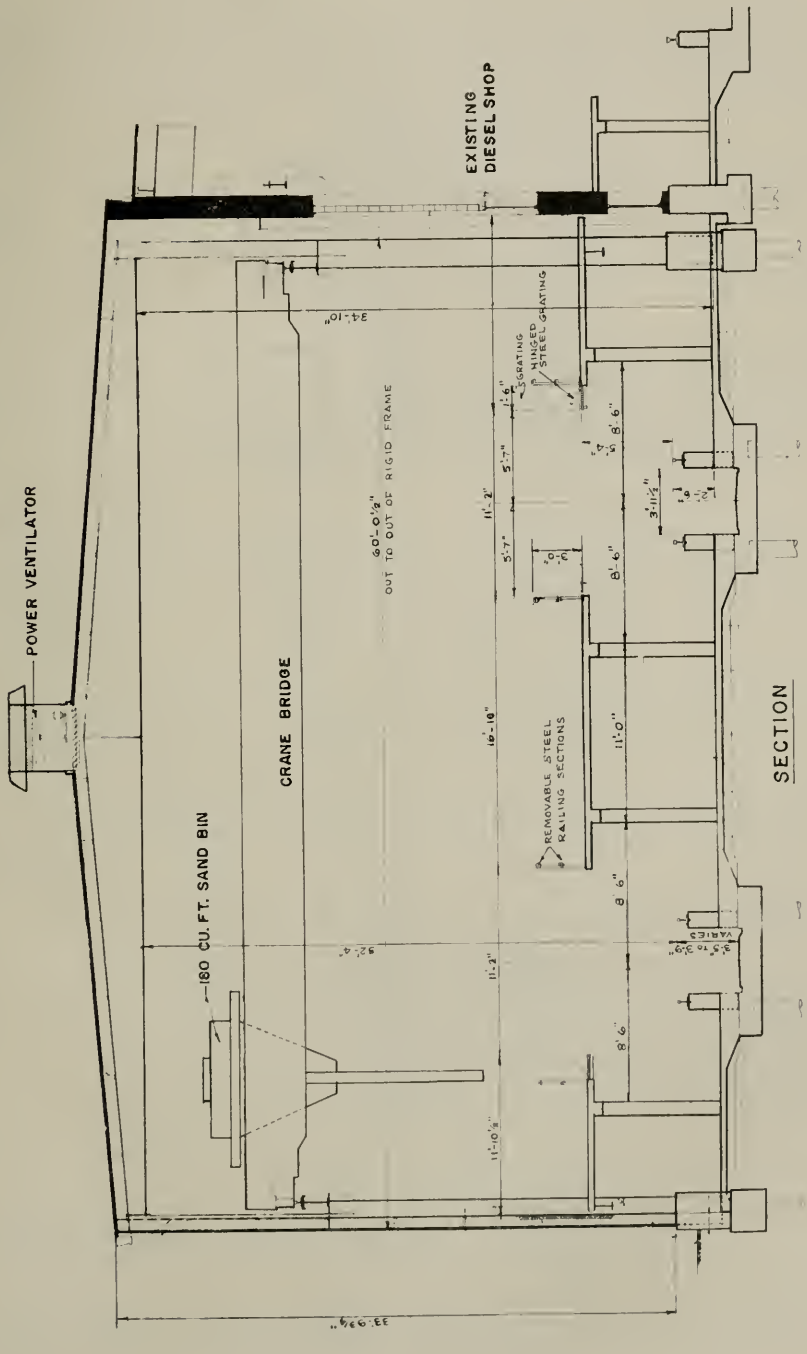
6.2.6 The disadvantages of extensive green sand storage are that considerable space for bins is required and that handling sand to the drier with hand labor is costly, especially as the material in storage lessens, except where overhead storage is used.

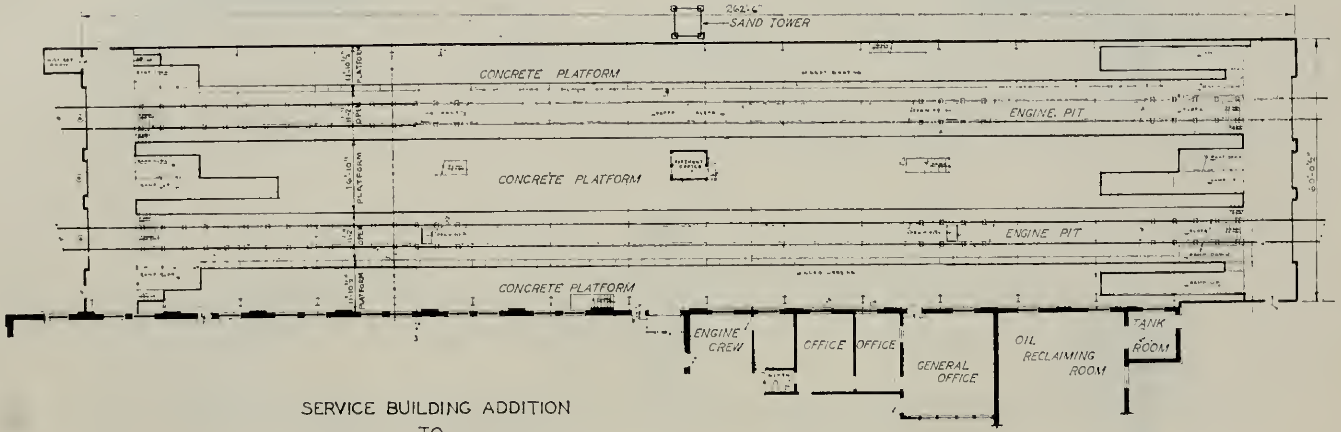
6.3 STORAGE AND SERVICE TANKS

6.3.1 Concrete or steel storage tanks will render satisfactory service for dry sand.



SERVICE BUILDING ADDITION
TO
EXISTING DIESEL REPAIR SHOP


POWER VENTILATOR
EXISTING DIESEL SHOP
180 CU. FT. SAND BIN
CRANE BRIDGE
60'-0½" OUT TO OUT OF RIGID FRAME
34'-10"
32'-4"
33'-9¾"
11'-2"
16'-10"
11'-2"
11'-10⅛"
1'-6"
5'-7"
5'-7"
3'-0"
GRATING
HINGED STEEL GRATING
8'-6"
5'-4"
2'-6"
3'-11½"
8'-6"
11'-0"
8'-6"
8'-6"
REMOVABLE STEEL RAILING SECTIONS
3'-5" TO 3'-9" VARIES
SECTION



SERVICE BUILDING ADDITION
TO
EXISTING DIESEL REPAIR SHOP

6.3.2 The service tank at track side is generally of steel construction mounted on a steel column or as an integral part of the sand storage silo, at a suitable elevation to permit loading sand into locomotive sand boxes by gravity through pipe and hose connections. Capacities of 5 to 10 tons are satisfactory for these latter tanks, the size being determined by the quantity of sand handled.

6.3.3 Service tanks into which sand is loaded by the use of air should be equipped with approved dust arrestor to release the air and retain the dust within the tank.

6.3.4 The tank should be equipped with approved signals to indicate when the tank is full and when the point of depletion is approaching.

6.3.5 Equipment is available to transfer sand automatically from the dry storage tank to the overhead smaller servicing tank. This obviates the necessity of assigning labor to keep sufficient sand in the servicing tank or delaying the sanding of a locomotive because of an insufficient supply of sand in the servicing tank. The importance of the operation should determine if such a refinement is justifiable.

6.4 UNLOADING

6.4.1 Green sand may be unloaded from cars either by hand shoveling into bin, by clamshell bucket, or by a belt conveyor system elevating the sand from a pit beside or beneath the car into the green storage bin. The choice of operation will be determined by the importance of the servicing point.

6.4.2 Bulk dry sand may be unloaded from box cars either by hand shoveling, or by the use of wheelbarrows or large scoops mounted on casters. The sand is pushed from the car into a hopper outside the car door and is elevated by a conveyor into the storage tanks. This is an expensive method of unloading.

6.4.3 The most economical method of unloading dry bulk sand is from totally closed hopper-bottom cars or from box or rebuilt tank cars with hopper bottoms. These cars can be spotted over a hopper built into a pit, into which the sand can be discharged:

(a) A simpler method whereby the pit, etc., is eliminated is to draw the sand from the car by the use of air-operated vacuum devices and discharged directly into the sand elevating tank.

(b) On very large installations a sand crane should be included. This crane usually has a 10-ton hopper on it which is filled by gravity from the elevated sand tank. The crane operator fills the engines with sand while standing on a platform suspended from the crane. From this platform, which is movable, all the openings in the diesel can be reached. With the crane runway 280 ft long, 4 engines can be sanded without uncoupling.

6.4.4 If air is used in elevating the dry sand, the elevated tank used in such an arrangement should be equipped with a small air release at its top to relieve the air as the tank fills with sand.

6.4.5 Tank cars may be rebuilt with inside hoppers to discharge sand through a valve or valves in the bottom of the car either to an underground elevating drum by gravity, or by air direct to the dry sand storage tank.

6.4.6 Mechanical shovels are available for removing sand from a box car to a hopper at the car door, but such equipment should be thoroughly investigated for the specific conditions under which it is to be operated.

6.4.7 Obviously, the unloading of sand should not be undertaken in the open in wet weather.

6.5 TRANSFER FROM STORAGE TO SERVICING TANKS

6.5.1 This operation is handled by installing the dry sand storage tank at an elevation sufficient to permit the sand to discharge by gravity into an elevating tank for distribution to the servicing tanks. This operation can likewise be handled automatically, thus reducing labor costs.

6.6 DRYERS

6.6.1 Stove dryers, steam dryers, and oil and gas-fired dryers of the hopper or rotary cylinder type are available, and each has its place, depending upon the demands of the station.

6.7 ELEVATING PIPE

6.7.1 It is obvious that sand handled under air pressure is abrasive to the pipe carrier. For such lines 2½-in flanged pipe should preferably be used. At connections the pipe ends should butt so that no space whatever exists between them which would permit cutting action to begin and wear down the pipe to a point where it enters the fitting.

6.7.2 At points in the line where sharp bends are necessary, either a heavy T or, preferably, a Y connection should be used with a short piece of pipe plugged and fastened to the dead end of the fitting. This forms a pocket which fills with sand for deflection purposes. It has been determined that where the direction of flow is changed the ricochet of sand just beyond the fitting causes a greater wear in the pipe there than elsewhere. It is a good practice to introduce a flanged replacement pipe section not less than 18 in long immediately beyond the T or Y fittings. All pipe should be installed so it is accessible for replacement.

6.7.3 Certain conditions may require placing a section of elevating pipe so as to offset some obstacle, or space may permit a long-radius curve in the change of direction. Specially manufactured hose is available for such locations and in some installations has outlasted pipe. If such material is used the life of the hose will be extended if it is rotated a quarter turn at intervals.

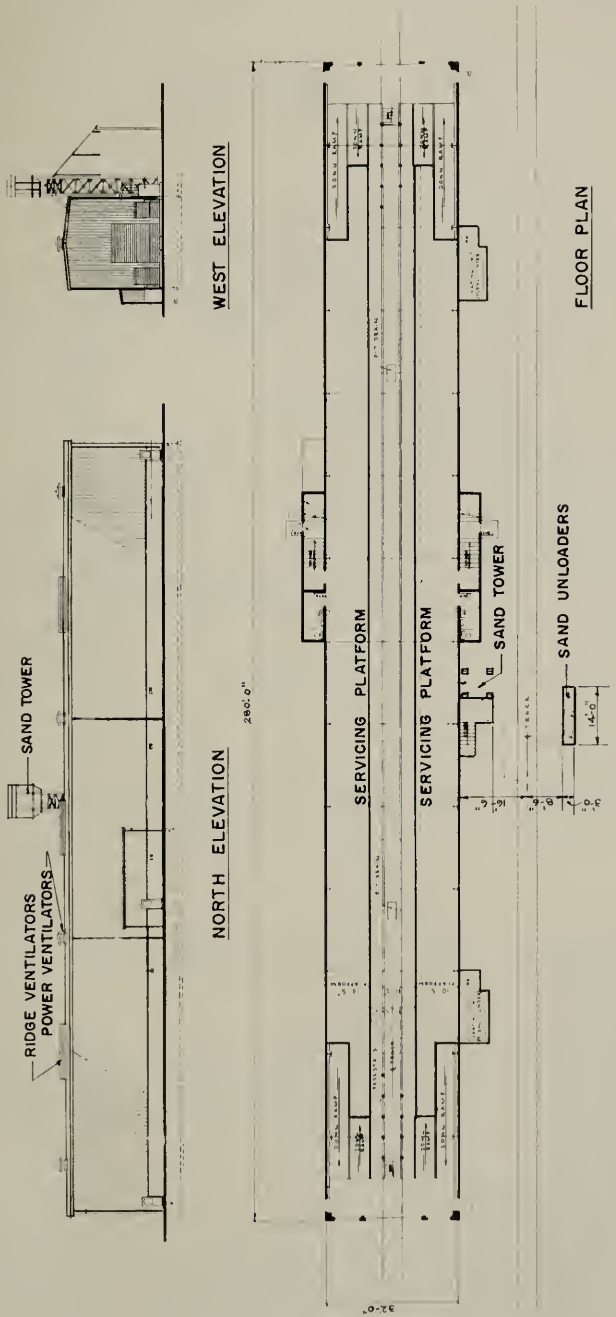
6.8 AIR PRESSURE

6.8.1 The minimum air pressure that can be used to move sand is desirable, as lower pressures materially reduce the wear in the pipe. Therefore, it is desirable to place an air reducing valve in the air supply line and cut the pressure to the minimum required to move the sand.

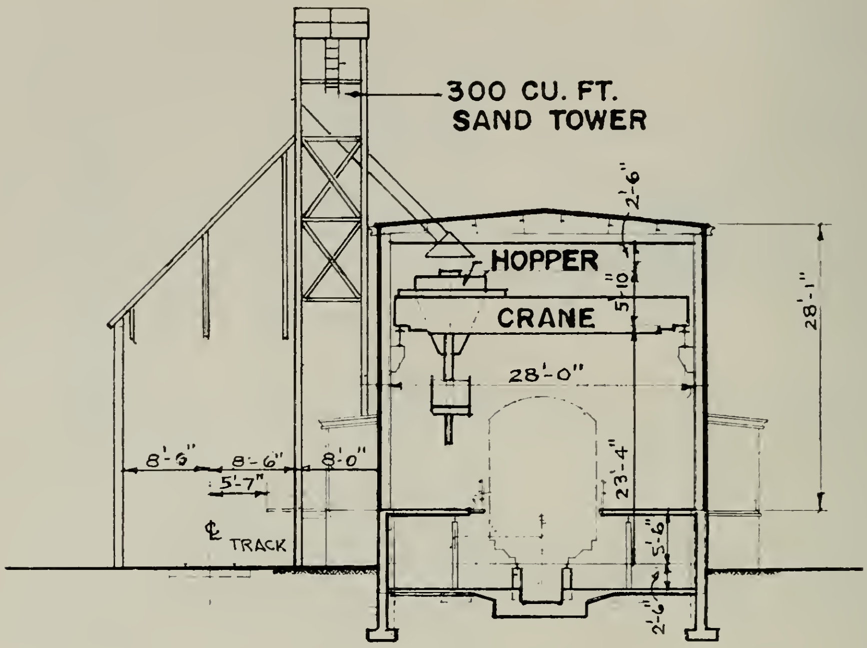
6.8.2 Dry sand can be moved through 2½-in pipe for horizontal distances up to 300 ft at 70 lb air pressure.

6.9 ELEVATING TANKS

6.9.1 Elevating tanks should be of the approved unfired pressure type with suitable valves for admitting sand and air. The tank should be fitted with a relief



DIESEL SERVICE BUILDING



SECTION

DIESEL SERVICE BUILDING

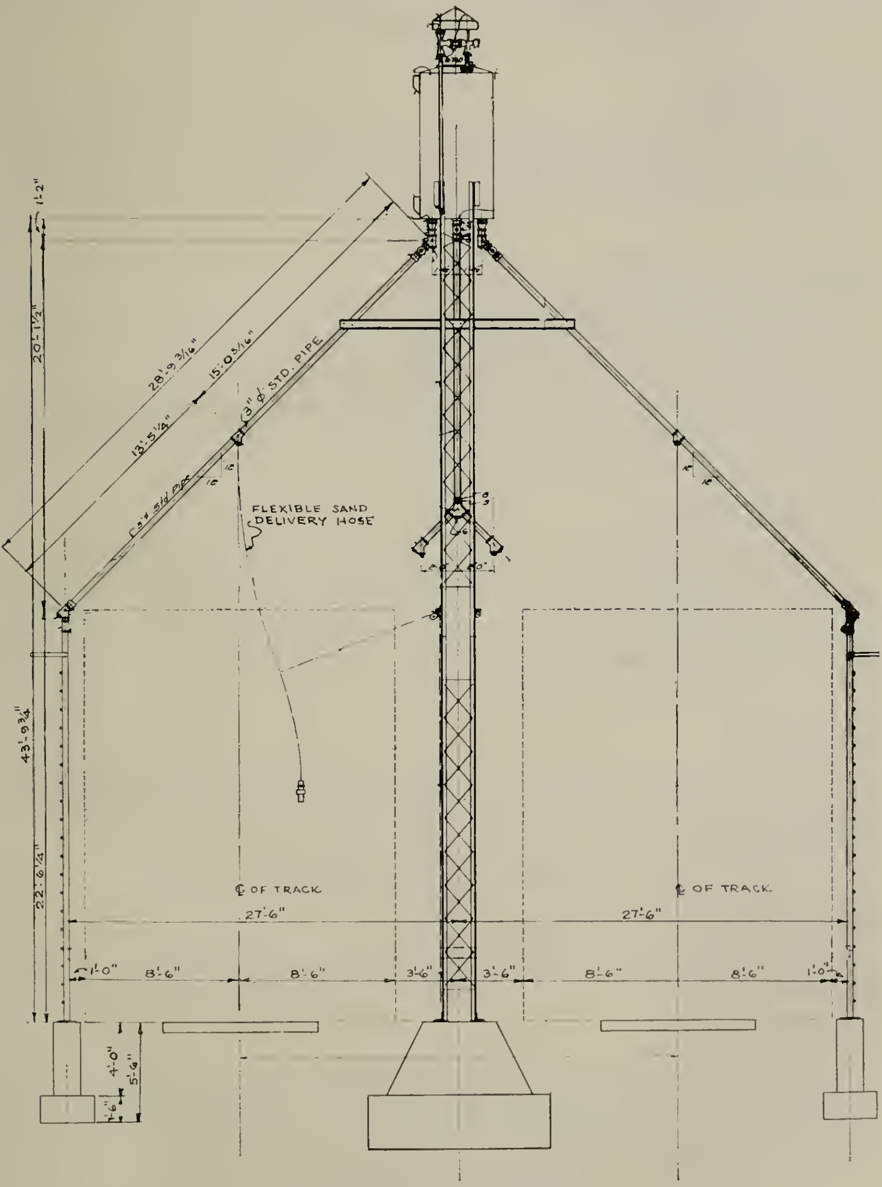
cock to release the pressure after the elevating operation when the handling of sand is manually controlled.

6.10 SAND COCKS

6.10.1 Where necessary to use sand shutoff cocks in an elevating line to change the flow of sand from one servicing tank to another, care should be exercised in selecting a suitable cock, as these units will quickly be worn by the sand if they are not rugged enough in design and material.

6.11 GRAVITY LOADING LINES

6.11.1 Gravity loading lines should be not less than 2½-in pipe leading at an angle of 45 deg from the overhead servicing tank to the sanding platform. These pipes should be installed so as not to encroach on the clearance lines. These delivery pipes are generally supported on posts above the platform. A Y connection is desirable at the platform end to permit a cleaning or rodding of the line in case of stoppage.



TYPICAL SAND TOWER

6.11.2 Valves should be placed in these lines at the service tank connection to permit shutting off the sand when necessary to work on the delivery pipe, hose or nozzle. Suitable lines should be provided for reaching top sand boxes on certain types of switcher locomotives.

6.12 NOZZLES

6.12.1 Control of flow of sand is desirable to avoid spillage at the sand box where it is loaded. Various types of nozzles are available. Care should be exercised to obtain a weather-proof unit. The size of the nozzle should be given consideration to be sure it will fit into the sand box.

6.13 AIR LOADING

6.13.1 At sanding points where the demand is light, equipment can be arranged for loading sand into locomotive boxes directly from the dry sand storage tank, by use of air obtained from the locomotive. This method of loading eliminates the need of the elevated servicing tank necessary for gravity loading. Air pressure should be carefully controlled to avoid the dust resulting from excessive blowing into the sand boxes. While this system has been used successfully, it is not generally accepted as the most desirable system due to the close control of air required.

6.14 PLATFORM

6.14.1 Platforms built parallel to the track and at a suitable height conveniently to reach sand boxes on the sides of locomotives are desirable. Light steel framing with steel open grating for the deck is a much-used type of construction. The platform should preferably be long enough to extend from the front to the rear sand boxes of a locomotive unit or units, depending upon the arrangement of the sand delivery pipes.

6.15 TRACK

6.15.1 The track for unloading either green or dry sand should be arranged so as to cause the least interference with the movement of trains and locomotives through the yard.

6.15.2 It should be an independent track used only for that purpose.

6.16 LIGHTING

6.16.1 Suitable lighting should be provided at the sanding platform if night servicing is required.

6.17 LOCATION

6.17.1 If space is available, the sanding and fueling spots should preferably be on the same track, but not closer than 50 ft. In this way the operations may be performed quickly and in sequence without fouling one another.

Part 7

Pre-Engineered Metal Buildings

7.1 FOREWORD

(a) The term "Pre-Engineered Metal Buildings" has largely superseded prefabricated metal buildings as the reference metal building manufacturers make to their product. In an industry which sells a product designated as pre-engineered, connoting standardization and ease of selection for the buyer, there is actually very little standardization in the finished product.

(b) The products of the metal building manufacturers are, primarily, basic components that can be arranged in myriad configurations; any designer's particular space and volume needs can be easily converted, generally by computers, into a package of components ready for quick assembly into a completed structure.

(c) Computer design capability has made it possible for every building to be designed, and its components fabricated, to fit width, bay length and load (dead, live, wind and moving) requirements. Dimensions of the major structural members of a metal building can vary in mid-span; the computer analyzes the load condition in short increments along the span and determines the amount of steel needed to carry the load in any given spot. Matching the steel member configuration to the load can thus produce a varying cross-section in the roof beam and side column.

(d) In practice, most, if not all, producers of metal building systems have adopted a concept of designing to fit the function, and will produce a building in any dimensions that meets the individual need.

(e) Pre-engineered buildings may be used for almost every type of structure inherent to the railroad industry. Consult the appropriate part of Chapter 6 for the design criteria for the particular type of building to be constructed.

7.2 STRUCTURAL TYPES

7.2.1 Self Framing

(a) In the self framing building the wall and roof panels are used structurally as load-bearing members to provide the necessary support to resist wind and live loads without the use of structural framing.

(b) Advantages:

1. Simplified foundations requiring no column piers or pier footings.
2. Portability.
3. Economical construction methods.
4. Maximum useable space.
5. Fast occupancy.
6. High value per investment dollar.

(c) Disadvantages:

1. Advantages diminish as cube of building increases.
2. Length of self-supporting panels is limited.
3. Additional independent framing is required for any load-carrying devices such as hoists or cranes.

(d) Applications:

1. Small offices.
2. Pump houses and compressor buildings.

3. Utility and storage buildings.
4. Lunch, locker and toilet buildings.
5. Section buildings.
6. Small stations.

(e) Size Range:

1. Width—5 ft 4 in to 32 ft 0 in
2. Length—smaller buildings—16-in increments.
   larger buildings—4-ft 0-in increments.
3. Height—8 ft 0 in to 14 ft 0 in.

(f) Roof

1. Single slope for smaller buildings.
2. Gable roof for larger buildings.

7.2.2 Rigid Frame

(a) This type of building is a continuous frame, consisting of rafters (tapered or uniform depth) rigidly connected to vertical, fixed, or pin-based column (tapered or uniform depth). The frame spans across the width of the building and is based on predetermined bay lengths and supports the secondary framing and the roof and wall covering.

(b) Advantages:

1. Economical clear spans.
2. Can provide support for interior load-carrying devices.
3. Simplified foundation design.
4. Interior partitions may be located independent of rigid frames.
5. Ease of expansion.

(c) Applications:

1. Office buildings.
2. Shop buildings.
3. Warehouses and storehouses.

(d) Size Range

1. Width—20 ft 0 in to 120 ft 0 in.
2. Length—Multiples of 20 ft 0 in to 28 ft 0 in bays.
3. Height—8 ft 0 in to 24 ft 0 in.

7.2.3 Beam and Column

(a) The beam-and-column building utilizes a tapered or unform depth beam or girder supported on interior and sidewall columns and is a multi-span structure. The primary framing is based on predetermined bay lengths and supports the secondary framing and the roof and wall covering.

(b) Advantages:

1. Wide span without interior or valley roof gutters.
2. Flexibility of bay arrangements.
3. Overall economy.
4. Can provide support for interior load-carrying devices.

(c) Applications:

1. Office buildings (including 2 story)
2. Warehouse and storehouse.
3. Shop buildings.

(d) Size Range
  1. Width 50 ft 0 in to 400 ft 0 in.
  2. Spans 25 ft 0 in to 80 ft 0 in.
  3. Length—Multiples of 20 ft 0 in to 28 ft 0 in bays.
  4. Height 10 ft 0 in to 24 ft 0 in.

7.2.4 Truss Frame

(a) The truss frame building utilizes a truss for its primary support member and may be either a single-span or multi-span structure. The truss properly braced is supported by columns. The primary framing is spaced on predetermined bay lengths and supports the secondary framing and the roof and wall covering.

(b) Advantages:
  1. Extremely wide spans are available with relatively simple foundation requirements.
  2. Structure has ability to accept large dynamic loads such as cranes.
  3. Truss space between lower chord and roof may be utilized for unit heaters, heat ducts, electrical fixtures, etc.
  4. Interior partitions may be located independent of building frame.

(c) Applications:
  1. Diesel shops.
  2. Heavy repair shops.
  3. Warehouses.

(d) Size Range:
  1. Width 60 ft 0 in to 120 ft 0 in.
  2. Length in bays—Varies.
  3. Height 12 ft 0 in to 40 ft 0 in.

7.3 SPECIFICATIONS

7.3.1 Manufacturers Specifications

(a) The "Performance Guide Specifications for Metal Building Systems" as published by the Metal Building Manufacturers Association is written to permit open competition between quality metal building manufacturers and provide the designer with an opportunity to make a selection from bids based on requirements of equal performance from various building systems.

7.3.2 Other Building Components

(a) Conventional specifications must be prepared for other building components to be provided by the metal building distributor or contractor.
  1. Concrete work
  2. Masonry
  3. Heating, ventilating and air conditioning
  4. Plumbing
  5. Sheet metal work (other than building)
  6. Earth work
  7. Electrical
  8. Equipment

7.4 STANDARDS AND CODES

7.4.1 Standards

(a) The following standards and criteria, of most recent issue, shall be used where applicable in the structural design of the building.

1. "Recommended Design Practices Manual," Metal Building Manufacturers Association.
2. "Steel Construction Manual," American Institute of Steel Construction.
3. "Cold Formed Steel Design Manual," American Iron and Steel Institute.
4. "Aluminum Construction Manual," The Aluminum Association.
5. "Code for Welding in Building Construction," American Welding Society.

7.4.2 Codes

(a) The following criteria shall also be applicable:

1. The building code having jurisdiction over the area in which the site is located.
2. Structural Steel Painting Council standards.
3. Federal and commercial standards.
4. ASTM standards.
5. Ratings by:
    a. Underwriters' Laboratories, Inc.
    b. Factory Mutual Engineering Association.

7.5 ECONOMIC CONSIDERATIONS

7.5.1 The Economy of Pre-Engineered Metal Buildings Is Derived From:

(a) Light foundation construction.

(b) Low erection costs.

(c) Low maintenance requirements.

(d) Portability and versatility.

(e) Speed of construction and ready availability.

7.5.2 Foundations

(a) Metal buildings exceed most classes of normal railway construction in strength rather than mass to resist natural forces; this in turn lessens the direct soil bearing. Footings support a minimum direct load.

(b) In instances where foundation material is good, the dead and live loads are light, the building is relatively small, and the effects of frost are neglible, footings may be eliminated in favor of a concrete slab with the perimeter thickened.

(c) When a column-supported system is used, it may be that all foundation can be eliminated with the exception of column piers and footings, dependent on code requirements and building usage.

(d) Savings in the forming and pouring of reinforced concrete can be considerable in an installation of even moderate size.

7.5.3 Erection Costs

(a) Once the materials are on the site, a major cost benefit of the metal building system becomes evident. The building contractor (normally a franchised dealer for the selected building system manufacturer) brings in his own crew to erect the building framework and then cover it with paneling that is cut to fit and, in some instances, prepunched to match holes prepunched in the structural members.

(b) Under normal conditions, the components that make up the metal building system can be on the job site ready for erection in a much shorter time than materials for conventional construction.

7.5.4 Maintenance

(a) Lower maintenance is derived from the all-metal construction; however, periodic painting of a galvanized steel covering may be required to extend its life, or for appearance.

(b) Where various protected metals or non-corrosive metal coverings are used, painting may be eliminated.

7.5.5 Portability

(a) One of the possible advantages is that of portability and re-erection at a new location. The buildings with fully bolted connections are designed in multiples of standard units and can in many cases be dismantled and re-erected at another site.

(b) A change of location requires the preparation of a new site and foundation which by the nature of the construction is minimal.

(c) It must be recognized that all refinements or elaborate finishes added to the building, including such items as lighting, heating, plumbing, drainage, lining, insulation, etc., complicate the procedure. However, the building shell is subject to being dismantled and moved economically with fewer complications than any other form of construction.

7.5.6 Availability

(a) Once the need exists for a new building, not having that building costs money:

1. In less efficient procedures.
2. In inadequate storage space.
3. In the intangibles related to personnel environment.

(b) It is the duration of these costs that the selection of a pre-engineered building can reduce.

(c) The shorter the construction period, the better. If time is of utmost importance, the pre-enginered building could well be the optimum approach.

7.6 FINISH MATERIALS

7.6.1 Exterior Finishes

(a) Many metal buildings require no additional exterior treatment. The need of such treatment, in fact, would be incompatible with the selection of a pre-engineered building. This would include:

1. Yard buildings.
2. Wayside buildings.
3. Storage and warehouse facilities.

(b) Much can be done to alter the appearance of metal buildings with the incorporation of contrasting materials on the exterior.

(c) Masonry materials can be successfully used, but special provisions must be made in the basic structure. Additional foundation and footing would probably be required, and vapor barriers, flashing, waterproofing and masonry ties should be considered.

(d) Painting the exterior of galvanized buildings is optional in most cases. Manufacturers recommendations should be followed as to type of metal coating most suitable to receive paint, the type of paint and preparation and application.

(e) In response to the growing demand for aesthetic metal buildings, the manufacturers introduced color to building exteriors. Beginning with coatings that were field applied after the building was erected, the industry moved to the use of prefinished metal, coil-coated steel or aluminum with a baked-on finish.

(f) Each metal building coating has individual characteristics:

1. Color retention.
2. Freedom from chalking.
3. Ability to shed dirt.
4. Resistance to physical abuse.
5. Resistance to chemical atmosphere.

(g) Basic to the metal building industry are these coatings:

1. Polyesters.
2. Acrylics.
3. Silicone polyesters.
4. Silicone acrylics.
5. Vinyl resin plastisols and organosols.
6. Polyvinyl and polyvinylidene chlorides.
7. Polyvinyl and polyvinylidene fluoropolymers.
8. Acrylic dryfilm laminates.
9. Fluoropolymer dryfilm laminates.

(h) Considerations in selecting an exterior coating for a metal building system:

1. The environment in which the building will be located.
2. The atmosphere surrounding the building.
3. The pollutants that will be attacking the coating.
4. The proposed life of the building.
5. The comparative costs of the suitable coating materials.

7.6.2 Interior Finishes

(a) In many cases the interiors require no finish other than the basic surfaces. If an interior finish is required inside walls may be finished with:

1. Plaster board.
2. Hardboards.
3. Plaster.
4. Metal panels.
5. Masonry veneers.

(b) It is a prerequisite of inside comfort that the sidewalls and ceiling be adequately insulated.

(c) Sandwich wall panels are generally available that contain insulating material between finished exterior and interior metal panel surfaces.

(d) Ceilings may be treated in a variety of methods. Most of the suspended systems are suitable and the frame of the building may be used as a suspension base. A suspended ceiling has the advantage of providing space for required electrical wiring and heating and cooling ductwork.

7.7 SERVICES

(a) The additional services, heat, air conditioning, light, and plumbing required to finish a metal building offer no particular problem. All systems can be installed by the manufacturer's representative as part of the overall building. In this instance supply and drainage lines must be provided, generally to within 10 ft of the foundation.

(b) The problems of providing services for a metal building are not markedly different from any other type of building. The general building type offers no inherent obstacles.

Part 8

Design Criteria for Railway Passenger Stations

8.1 FOREWORD

8.1.1 General

(a) A passenger station comprises the buildings, tracks, land and all appurtenances devoted to passenger traffic within the limit of the site. These design criteria will be limited to the building and its platforms used exclusively for passenger purposes.

(b) While service is the primary consideration, the style and finish of a passenger station should, if practicable, be in keeping with the civic spirit of the community.

8.1.2 Types of Stations

(a) Passenger stations may be classified as follows:

1. Shelters
2. Wayside stations.
3. Combination freight and passenger stations.
4. Individual passenger stations.
5. Metropolitan passenger terminals.
6. Suburban passenger stations.

(b) Shelters are small open structures provided for the accommodation of passengers at small communities or outlying points in larger cities. They are usually one of two types:

1. An umbrella-type roof with a partition running longitudinally through the center of the area below with or without benches.
2. A three-sided structure with only the track side open (see Fig. 1).

(c) A wayside station is a small passenger station provided at local stops where volume of business does not warrant a larger structure (see Figs. 3 and 4). Portable buildings may be used as wayside stations and may be readily located when volume of business changes. (See Fig. 2).

(d) Combination freight and passenger stations are well adapted to small communities where freight and passenger volume is not sufficient to warrant separate facilities. This type of station usually includes a waiting room, an office, a baggage room and a freight house. (See Figs. 5, 6 and 7).

(e) Individual passenger stations are constructed where volume of business or railroad operations require separate freight and passenger facilities. (See Figs. 8, 9 and 10).

(f) Metropolitan passenger stations which are located in downtown areas of large cities generally incorporate additional space for restaurant facilities, concessions and office space available for rental, as well as the basic facilities required for the operation of the passenger station. (See Figs. 11 and 12).

(g) Suburban stations are distinct from other types of passenger stations in that they serve only commuters. They will vary in design from shelters, to heated waiting rooms (see Fig. 13) to larger stations which have all of the facilities of a through passenger station.

(h) The design criteria contained herein may apply to one or all types of station and the designer will have to select information required for his individual needs.

8.1.3 Definitions

1. Stub Station—One in which the station tracks are connected at one end only.

2. Through Station—One in which the station tracks are connected at both ends.

3. Passenger Platform—A station platform which is used only for the accommodation of passengers.

4. Trucking Platform—A station platform which is used only for the handling of baggage, mail and express.

5. Combined Platform—A station platform which is used for the joint accommodation of passengers and the handling of baggage mail and express.

8.2 SITE CONSIDERATIONS

8.2.1 Location

(a) The location of a passenger station should be determined by the requirements of train operation. The possibility of locating passenger terminals to areas contiguous to freight terminals should be considered. This permits freight yard crews to handle passenger station switching and freight carmen and yardmen to handle passenger station servicing.

(b) Because of constantly increasing terminal costs and the steadily rising spiral of labor and service charges, it is imperative, in planning passenger station facilities, that prime consideration be given to economics, operating efficiencies and reduced operating costs.

8.2.2 Parking

(a) Adequate parking facilities at passenger stations should be provided for

1. Short-term occupancy for private automobiles awaiting train arrival or departure.
2. All-day parking for patrons who park their cars during daily working hours.
3. Long-term occupancy for patrons who may wish to park their cars for several days while away on trips.
4. Railroad office personnel and tenants.

(b) Parking lot entrances and exits should be well defined and should be planned to eliminate interference with street traffic so far as possible. Entrances should be located close to the station or train loading point.

(c) Drainage, grading and surface treatment for dust prevention should be provided. Bituminous paving is generally used, with the unit parking spaces delineated by lines painted on the pavement.

(d) Adequate lighting and suitable enclosure are desirable for safe operation of the parking lot and to prevent pilfering and vandalism.

8.2.3 Landscaping

(a) The architect should determine from local ordinances if landscaping is required and what percent of the site area must be landscaped. If there are no landscaping requirements by law, it is now generally considered good practice to provide some planting around the building or parking areas.

(b) The vegetation used in landscaping should be easy to grow in the climate involved and not too costly to maintain.

8.2.4 Coach Yards

(a) The passenger station complex may include an adjacent coach-yard facility for storage and servicing of passenger equipment. It may also be necessary to provide steam, air, water and a-c and d-c electrical standby outlets adjacent to station trackage to facilitate storing of equipment in the station area.

(b) Coach watering hydrants may have to be provided for passing trains as well as watering and fueling facilities for diesel locomotives.

8.3 FUNCTIONAL REQUIREMENTS

8.3.1 General Considerations

(a) The general layout and traffic-flow arrangements for passenger stations should be designed to permit the most efficient and expeditious handling of passengers while at the same time giving consideration to their convenience, comfort and safety.

(b) The requirements of through passenger and commuter service are so dissimilar that it is desirable to make a complete separation of the two classes of service.

(c) Characteristics of the through traveler and the commuter:

Through Traveler	*Commuter*
1. Frequently a stranger.	1. Generally familiar with the station.
2. Occasionally is unused to travel.	2. Is self reliant.
3. Often uncertain in movement.	3. Definite and brisk in movement.
4. Sometimes elderly or infirm and often accompanied by children.	4. Active and of adult age.
5. Generally carrying hand baggage.	5. With no luggage or only a small brief-case.
6. Occupies more space on platforms and for longer average time.	6. Moves promptly from train to exit.
7. Requires waiting room, toilets, ticket sellers, etc.	7. Requires no aid and wants none.

(d) Through and commuter business may be separated by:

1. Classes of service on different levels.
2. Providing separate facilities side by side.
3. By-passing commuter service beyond the terminal for through service.

(e) A complete separation of inbound and outbound traffic, particularly in large stations, is very desirable, so that there will be no conflict between lines of travel in opposite directions. The design should permit prompt handling of passengers transferring from one train to another.

(f) Principal station facilities, such as information booth, ticket office, baggage check counter, etc., should be located in proper sequence along the line of travel and clearly indicated so as to avoid confusion and reduce passenger walking distance to a minimum.

8.3.2 Concourse

(a) A train concourse is advantageous, as it permits serving of one station platform by several train gates or, conversely, the serving of several platforms from one train gate. In stub stations it permits trucking from one platform to another without entering the passenger concourse.

(b) A passenger concourse can be used effectively as an exit passageway which permits arriving passengers to reach the street without passing through the station.

(c) The concourse should be so arranged that it will not be a convenient thoroughfare for people who are not passengers.

8.3.3 Waiting Rooms

(a) The waiting room should be located to one side of the line of travel, but near to the passenger concourse and adequately equipped with bulletin boards, clocks and other information devices, so that passengers will be content to remain in the waiting room and not unnecessarily occupy the passenger concourse.

(b) Indicator boards showing track number, schedule and stops should be readily available. This may be augmented by public address systems.

(c) The ingress and egress areas between waiting rooms and trains will vary depending on train operation at the passenger station. At a dead-end station or a terminal point the passenger flow to trains would be parallel to the trains. The through station will require a paved area whereby passengers could cross tracks, or if warranted, underground tunnels or overhead bridges.

(d) The waiting room area should be basically uncluttered and rectangular in shape, with exits to the streets, trains and concession areas feeding off from the waiting room area.

8.3.4 Ticket Offices

(a) Ticket offices should be located adjacent to the direct line of travel, but should be so arranged that passengers waiting to secure tickets will not interfere with the general flow of traffic.

(b) Windows opening directly onto the concourse for sale of local tickets are desirable.

8.3.5 Offices

(a) In the planning and design of station buildings, consideration should be given to additional space for offices required for the operation of the station and, where possible, office space for rental.

(b) If offices are constructed in conjunction with the station, the office entrances should be independent so that employees will not be required to pass through the station.

(c) Requirements for offices built in conjunction with the station may be found in "Design Criteria for Railway Office Buildings," Part 2, this chapter.

8.3.6 Concessions

(a) Concessions of proper character are desirable not only from a revenue producing standpoint, but as a facility which adds to the comfort of the passenger.

(b) The number and character of concessions will be determined by the needs at each location.

(c) Concessions to be successful must be located so as to be conspicuous and easily accessible.

(d) Booths opening directly onto the corridor where service is rapid appeal more to the commuter. Stores appeal more to the through traveler and particularly to the transfer passenger who has time to spare.

(e) The extent of taxi cab facilities depends on:

1. The size of the city.
2. The character of the taxi cab service.
3. Other available means of local transportation.

8.3.7 Toilet Rooms

(a) Ample toilet facilities should be provided adjacent to the waiting room for public use.

(b) Additional toilet facilities should be provided for the office and train personnel.

8.3.8 Platforms

(a) Station platforms at car-floor level are superior to those at top of rail in that hazard and inconvenience resulting from use of car steps are eliminated and the handling of passengers is expedited. High platforms, however, interfere with equipment inspection.

(b) Separate platforms for passengers and trucking are advantageous as station operation is facilitated and passengers are saved the annoyance of trucking operations.

(c) Ramps are desirable where their use does not increase the distance traveled to reach a given point. Handling of large crowds is expedited.

8.4 SPATIAL REQUIREMENTS

8.4.1 General Considerations

(a) The size of facilities is subject to variation due to:

1. Local conditions.
2. Class of traffic.
3. Type of service.
4. Normal rush-hour business handled.

(b) The design of entrances and exits should be planned to minimize congestion of pedestrian and automobile traffic. Exit turnstiles are an inconvenience, slow up traffic and should be avoided. Exit gates should be approximately full width of platform to permit passage without causing a bottleneck.

(c) The movement of suburban passengers through openings is as follows:

1. Turnstiles (5 ft 4 in diameter)—50 passengers per minute.
2. Single swinging doors (3 ft 0 in wide)—77 passengers per minute.
3. Double swinging doors (6 ft 0 in wide)—117 passengers per minute.
4. Ticket gates (each ticket punched)—46 passengers per minute.

8.4.2 Concourse

(a) The required width of a passenger concourse depends upon the character and amount of traffic and number of entrances and exits to the concourse. A width of 20 ft 0 in for a train concourse is adequate if it is not used extensively for trucking.

(b) The concourse should be sufficiently broad to permit the gathering of a full trainload at the gate.

8.4.3 Waiting Rooms

(a) Passenger station waiting rooms should be designed for maximum normal occupancy, not for peak occupany. This is particularly true at locations which have unusually high seasonal peak loads. It may be desirable to furnish ticket sales and baggage checking facilities to accommodate these peak loads.

(b) Once the maximum normal occupancy has been determined, the area of the waiting room can be calculated by applying the generally accepted rule-of-thumb design factor of 13 sq ft of floor area per person. Experience has shown that this factor should be modified, depending upon the number of people to be accommodated, between a range of 10 and 15 sq ft per person. Smaller occupancies will require 15 sq ft per person. Larger occupancies will require only 10 sq ft per person. This results from more effective use of circulation space in larger facilities.

(c) While the rule-of-thumb factor has proven to be a dependable method of calculating required waiting room areas, local building codes should be consulted for possible conflicting requirements.

8.3.4 Ticket Offices

(a) The design of ticket office area can be developed on the basis of the use of standard cabinet units allowing sufficient space for ticket stock tariffs, telephone and other communications equipment.

(b) The baggage check and baggage storage areas should be properly oriented to the ticket area for the convenience of the patrons, and to facilitate the installation of luggage conveyor equipment.

(c) The number of ticket windows required should be based on the normal number of rush hour passengers. The following table is based on through travellers not commuters.

Passengers Normal Rush Hour	*No. of Windows Required*
1– 74	1
75–149	2
150–249	3
250–324	4
325–449	5
Over 450	1 additional window for every 250 passengers

(d) To determine the area required for the ticket office, a rule-of-thumb of 130 sq ft per ticket window may be used.

(e) Where a large number of commuter tickets are issued during the last two or three days of the month, portable booths located in the passenger concourse may be desirable.

8.4.5 Offices

(a) The areas containing railroad offices or leased space should be designed to meet railroad or tenant requirements. Consideration should be given to the use of moveable partitions to provide for flexibility.

8.4.6 Concessions

(a) The determination of requirements for newsstand and food dispensing concessions should be made jointly by local operating people and the concession operators. Of interest to both parties is the need to provide facilities adequate to meet the demand, and of a size that can operate efficiently and produce a profitable return to both the concessionaire and the owner.

(b) The requirements for other passenger service accommodations, such as parcel checking lockers, public telephones, automobile rental stations, travelers aid stations, Western Union service, taxi cab stand, etc., are also usually developed jointly by the local operating people who are familiar with the demand, and representatives of the concessionaire or service.

8.4.7 Toilet Rooms

(a) Applicable local codes should be used to determine fixture and area requirements.

8.4.8 Platforms

(a) Station platforms should be of sufficient length to provide access to all head-end cars as well as to passenger cars on the longest trains that will be serviced from the platform.

(b) The amounts of platform space utilized by passengers when moving in a compact mass, but without objectionable congestion, are as follows:

1. Through passengers—15 sq ft per passenger
2. Suburban passengers—10 sq ft per passenger

(c) Capacities of station platforms in discharging passengers are as follows:

1. Through passengers—15 passengers per foot of width per minute.
2. Suburban passengers—30 passengers per foot of width per minute.

(d) A 13-ft 0 in exclusive passenger platform is the minimum width sufficient to accommodate the passengers from one arriving train, plus one line of travel for passengers to a departing train.

(e) Exclusive trucking platforms should be of an adequate width to permit two loaded trucks to pass and should be free of columns. A width of 11 ft 0 in is recommended as a minimum for exclusive trucking platforms.

(f) Combined passenger and trucking platforms for normal conditions, allowing space on the platforms for one loaded truck, should be at least 18 ft 0 in wide.

8.4.9 Ramps, Stairs, Escalators and Elevators

(a) The gradient of a ramp should not exceed the following:

1. For passengers—10 percent
2. For trucking—6.5 percent

(b) The minimum clear widths which should be considered for trucking ramps are as follows:

1. For one line of traffic—6 ft 0 in.
2. For two lines of traffic—10 ft 0 in.

(c) For heights less than 25 ft 0 in under normal conditions, passenger elevators or escalators are not recommended as approaches to individual passenger platforms. They may be desirable as supplemental to stairs for the use of the aged or infirm.

(d) The carrying capacity of stairs decrease with increase in height. For a height of 20 ft 0 in the carrying capacity with traffic in one direction is as follows:

1. Through passengers—10 passengers per foot of width per minute.
2. Suburban passengers—18 passengers per foot of width per minute.

(e) In combined passenger and trucking platforms in through stations, it is desirable to have a space of 6 ft 0 in wide on one side of the stairs to permit trucking operations past the stairs.

(f) Escalators have a carrying capacity of approximately 33 passengers per foot of width per minute. They are well adapted to suburban service.

(g) A single elevator or escalator should not be relied upon as the sole means of approach to a station platform.

8.5 STRUCTURAL REQUIREMENTS

8.5.1 Structural Systems

(a) The type of construction will be influenced by the size and location of the facility. Small stations are generally constructed of masonry, are prefabricated metal buildings or are portable metal buildings. Larger stations would more likely have a structural steel or reinforced concrete frame with masonry or metal panel exterior walls.

(b) The building designer must use his own judgment in making the final decision for the type of construction.

8.5.2 Floor Systems

(a) Smaller stations can be constructed on concrete slabs or with crawl space. In crawl space construction wood or steel floor joint systems are used. Larger stations can utilize any adaptable floor construction system and should consider the use of underfloor duct systems for electrical and communication wiring.

(b) Recommended (minimum) live loads for various types of occupancy.

1. Offices	50 psf
2. Public corridors	100 psf
3. Light storage	125 psf
4. Rest rooms	50–100 psf
5. Public stairways	100 psf
6. Restaurants	100 psf
7. Waiting rooms	100 psf
8. Passenger platforms	100 psf
9. Trucking platforms	Maximum wheel load

8.5.3 Partitions

(a) Movable partitions are practical in office areas. Rearrangement can be made quickly and economically.

(b) Permanent type partitions such as masonry with or without finish are more practical and durable in public areas.

8.6 FINISH MATERIALS

8.6.1 Exterior Materials

(a) The selection of exterior materials will be largely dependent on the type of structural system selected. The location of the station will determine to a great extent the amount of aesthetic treatment.

(b) In many instances local building codes will require certain types of exterior finish or specify a minimum fire rating to be provided.

(c) The exterior treatment will also be influenced by the degree of permanency required of the building. A prefabricated or portable building which can reasonably be expected to be relocated should not have masonry or other permanent materials incorporated into its exterior treatment.

(d) The building designer must utilize his own judgment in the selection of materials.

8.6.2 Wall Ceiling and Floor Finishes

(a) The type of wall finish to be applied will be determined by the type of appearance required. Maintenance considerations will be an important factor.

(b) Although many materials may be considered the waiting room, corridors, lounges, toilet rooms and access areas to trains should be constructed of materials highly resistant to damage or defacement. Quarry tile or terrazzo floor surfacing should be provided in all the public areas. Ceramic tile or plastic surfaced materials should be considered for wall surfaces in public areas. Acoustical ceilings should be provided to help reduce the noise level.

8.7 MECHANICAL CONSIDERATIONS

8.7.1 Heating and Air Conditioning

(a) A proper ventilation system or a complete winter and summer air-conditioning installation should be provided throughout the public areas, restaurant, other concession areas, and the office area.

(b) Some of the more common systems used to heat smaller stations are:

1. Steam radiation.
2. Hot water radiation.
3. Baseboard convectors.
4. Forced warm air systems.
5. Radiant heating.

(c) Cooling of smaller stations can be economically accomplished by the installation of package-type air conditioning units incorporating air-cooled or water-cooled condensers.

(d) Individual small rooms or offices may be cooled by window-type units.

8.7.2 Plumbing

(a) Sanitary facilities should be located centrally, where possible, to reduce the amount of piping required. Toilet rooms should be back-to-back where practical.

(b) All main piping should be accessible to the degree possible to facilitate alterations and maintenance.

8.7.3 Lighting and Power

(a) The architect, with the help of an electrical engineer, must make a thorough study of the lighting and power requirements of the stations.

(b) Illumination levels for stations can be selected from IES Standards.

(c) Consideration must be given to lighting the building exterior, walkways and parking lot. The amount and type of lighting will be determined by the location.

(d) The design of the electrical system of the station is governed by local and national codes which must be strictly adhered to.

8.7.4 Elevators

(a) Stations of more than two stories should have an elevator, not only for passengers, but one equipped for conveying equipment and supplies.

8.7.5 Fire Protection

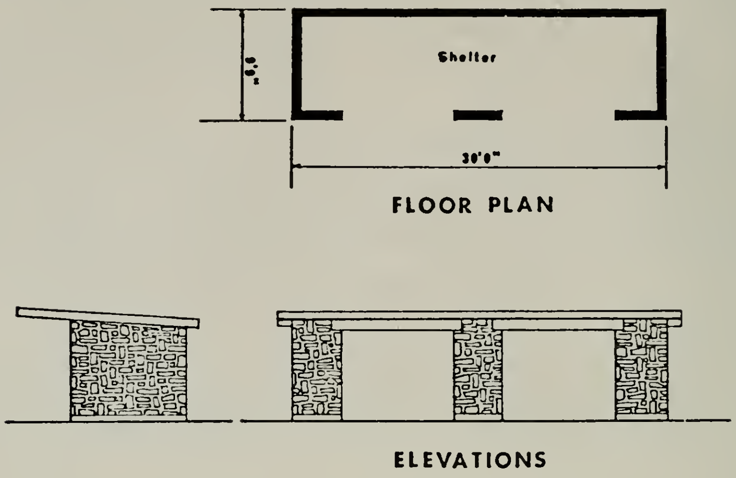
(a) Fire protection should be incorporated early in the design and planning of the station. Local codes should be observed.

8.7.6 Special Equipment

(a) Automatic door openers should be provided on exterior doors and doors between the waiting room and concourse for ease of passage for people carrying hand baggage.

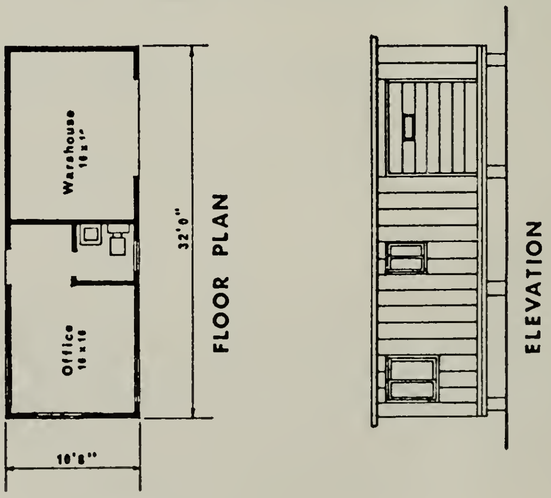
(b) Speaker systems and other communication installations should be provided throughout the station building and platform areas, both for directing patrons to and from trains and for use of railroad employees responsible for the operation of the passenger facility.

(c) Signaling and centralized control system should be provided in order to control movements of trains in and out of the station.



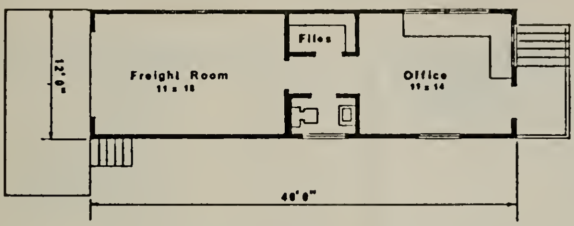
PASSENGER STATION
LAKE FOREST, ILLINOIS

Fig. 1

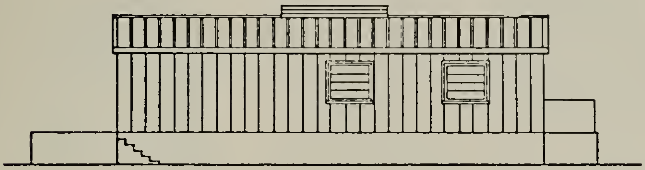


PORTABLE STATION
CENTRAL CITY, KENTUCKY

Fig. 2

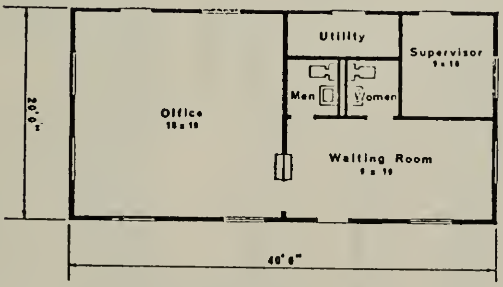


FLOOR PLAN

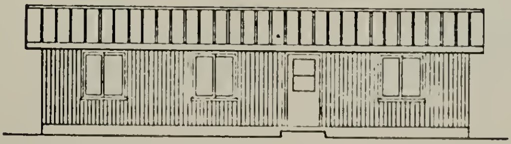


ELEVATION

PASSENGER STATION
ROSEDALE, MISSISSIPPI
Fig. 3

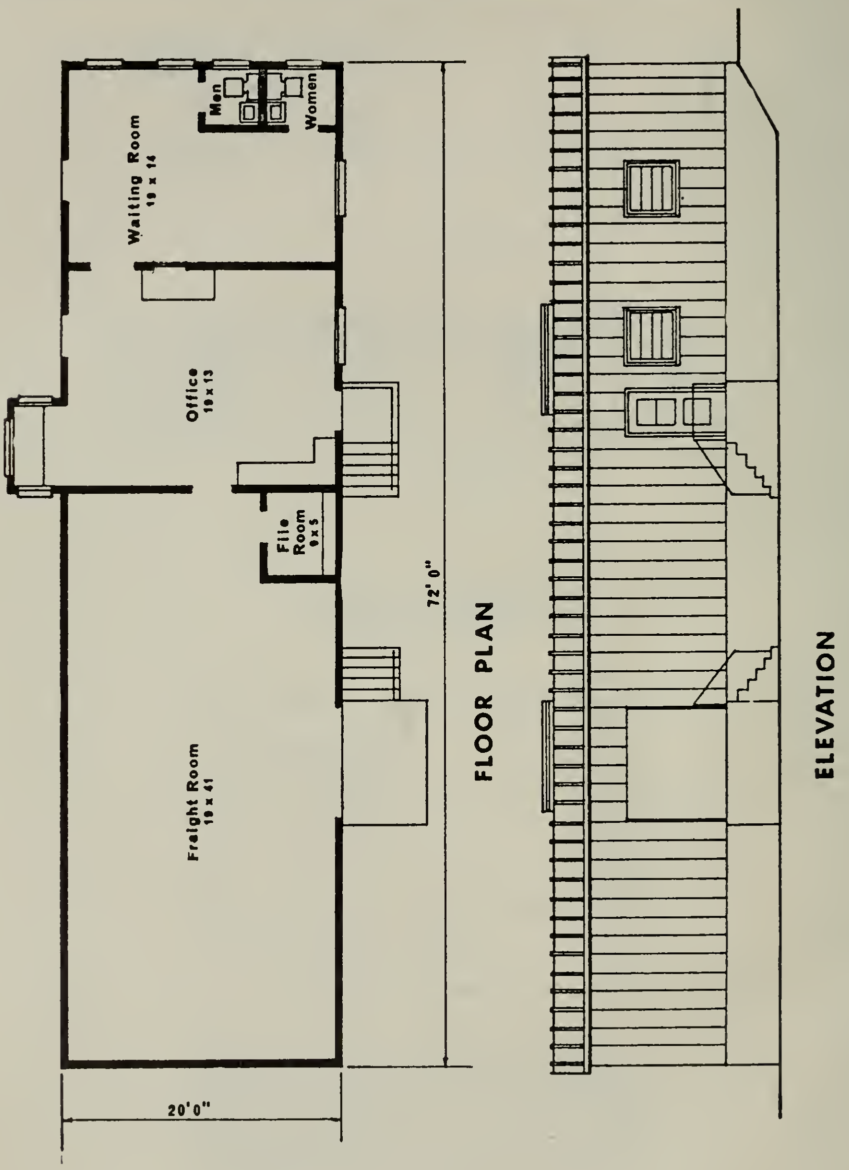


FLOOR PLAN



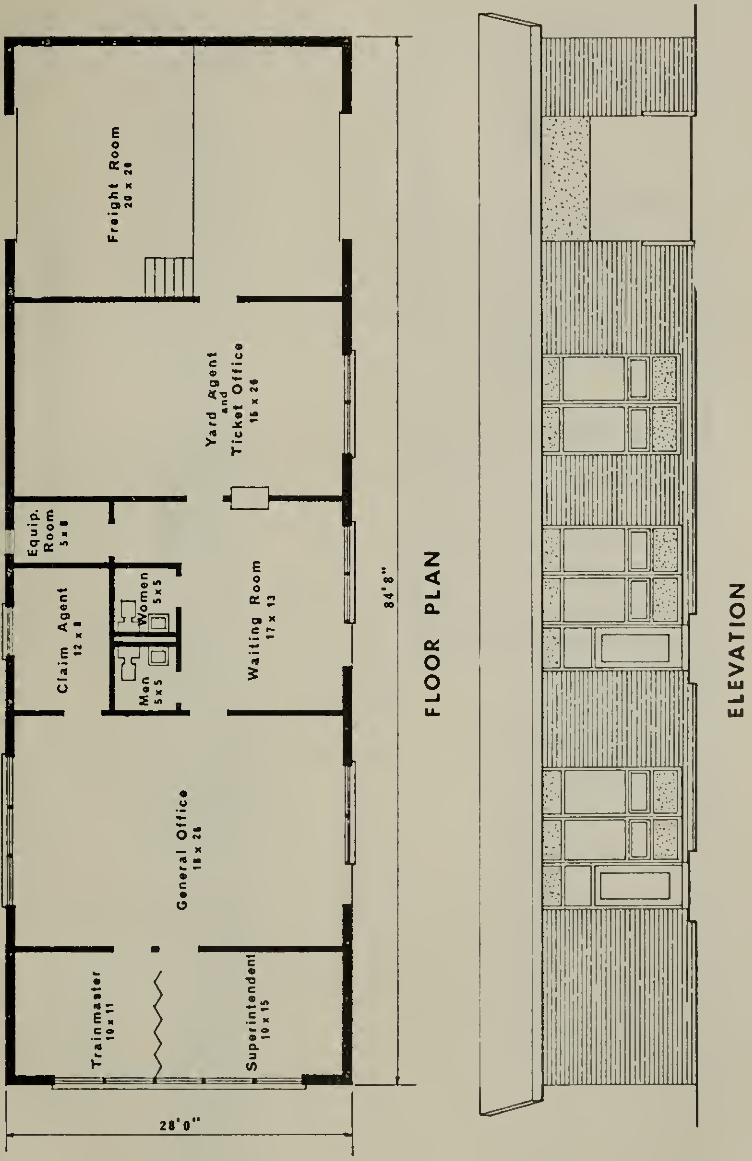
ELEVATION

PASSENGER STATION
DYERSBURG, TENNESSEE
Fig. 4

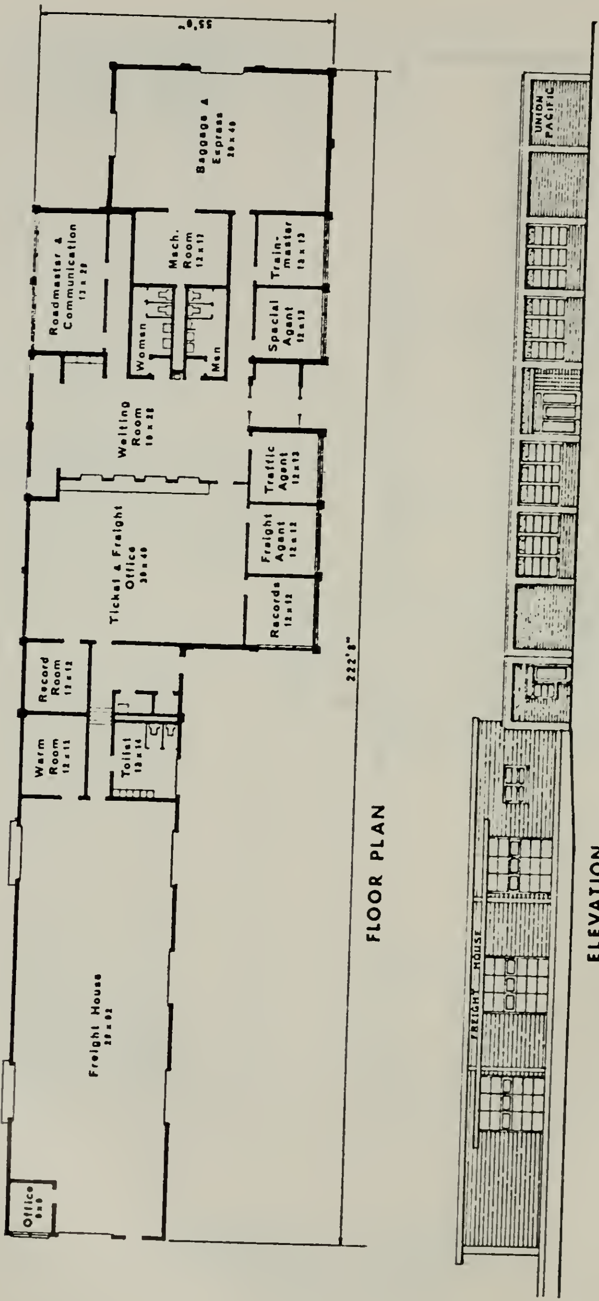


PASSENGER STATION
SENATOBIA, MISSISSIPPI

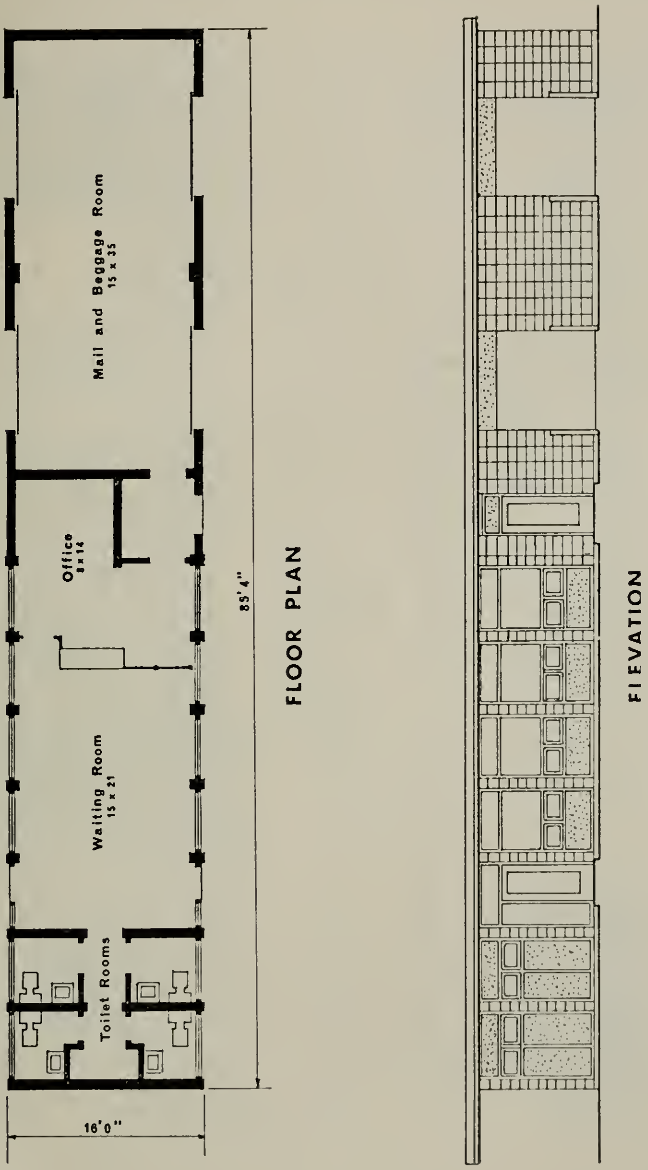
Fig. 5



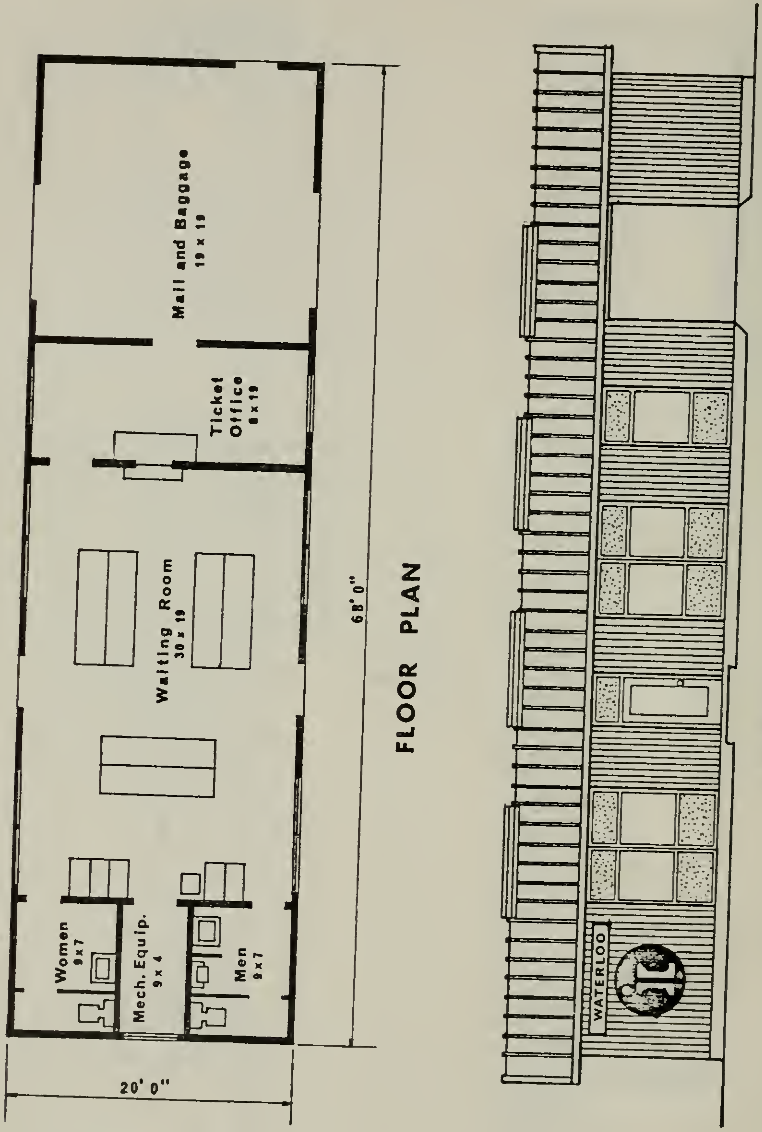
PASSENGER STATION
HOISINGTON, KANSAS
Fig. 6



PASSENGER STATION
IDAHO FALLS, IDAHO
Fig. 7

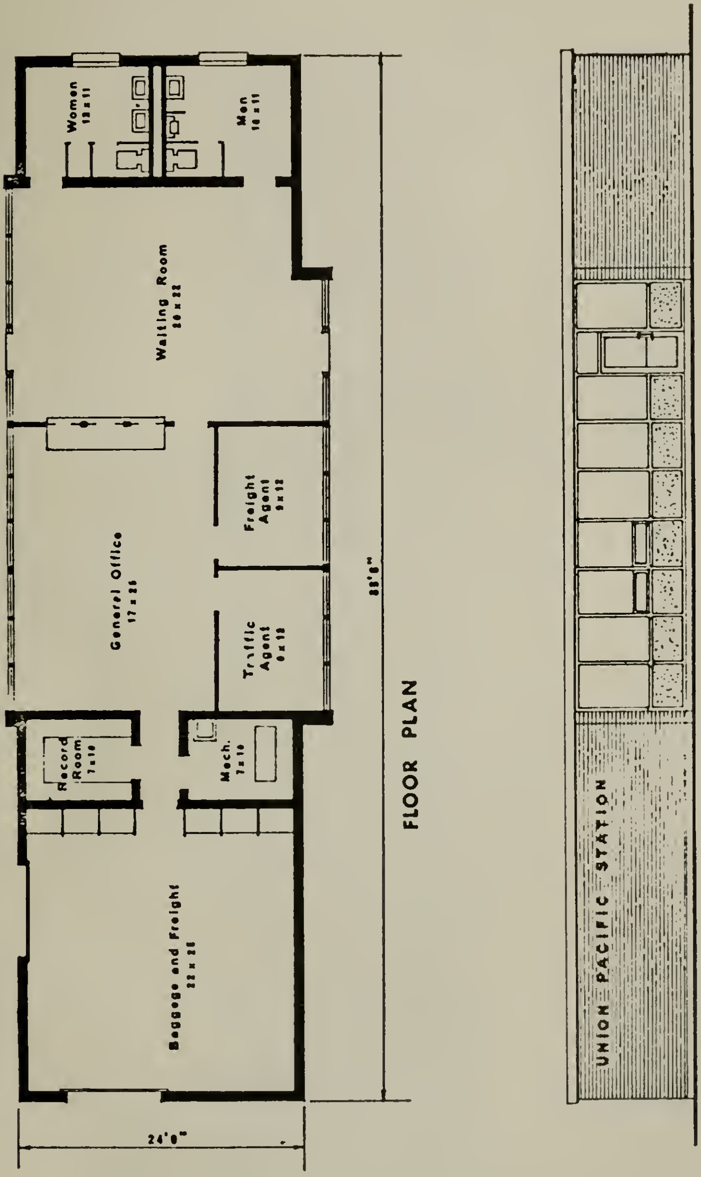


PASSENGER STATION
CUT OFF JC'T., LOUISIANA
Fig. 8



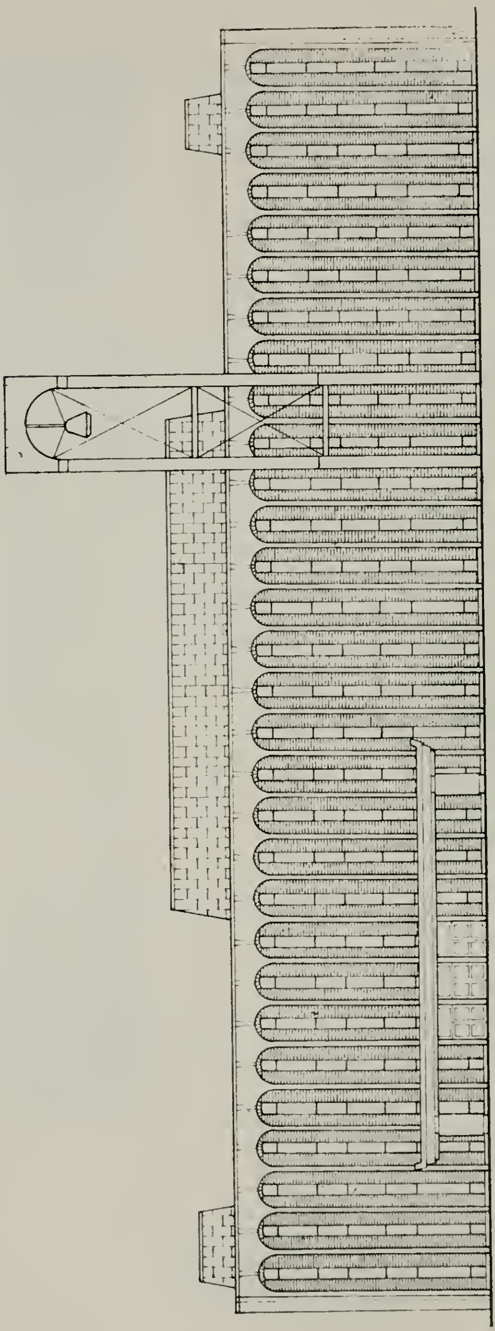
PASSENGER STATION
Waterloo, Iowa

Fig. 9



PASSENGER STATION
POMONA, CALIFORNIA

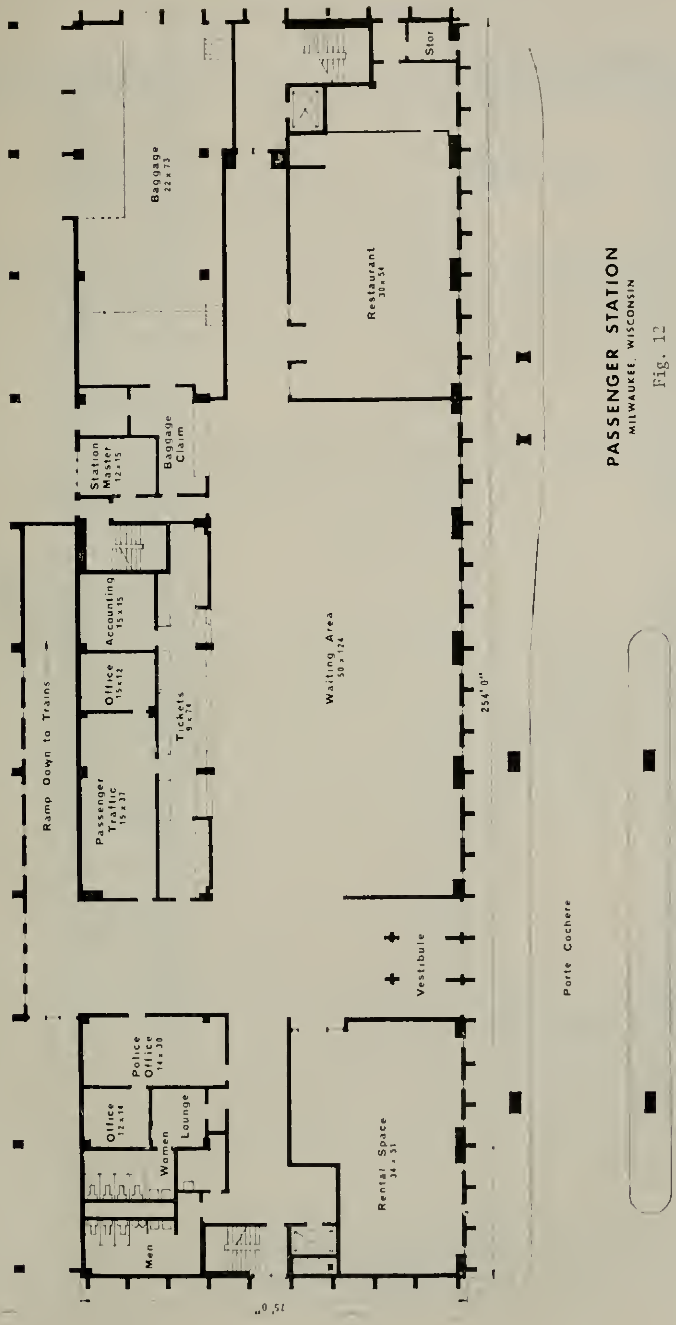
Fig. 10



FRONT ELEVATION

PASSENGER STATION
MILWAUKEE, WISCONSIN

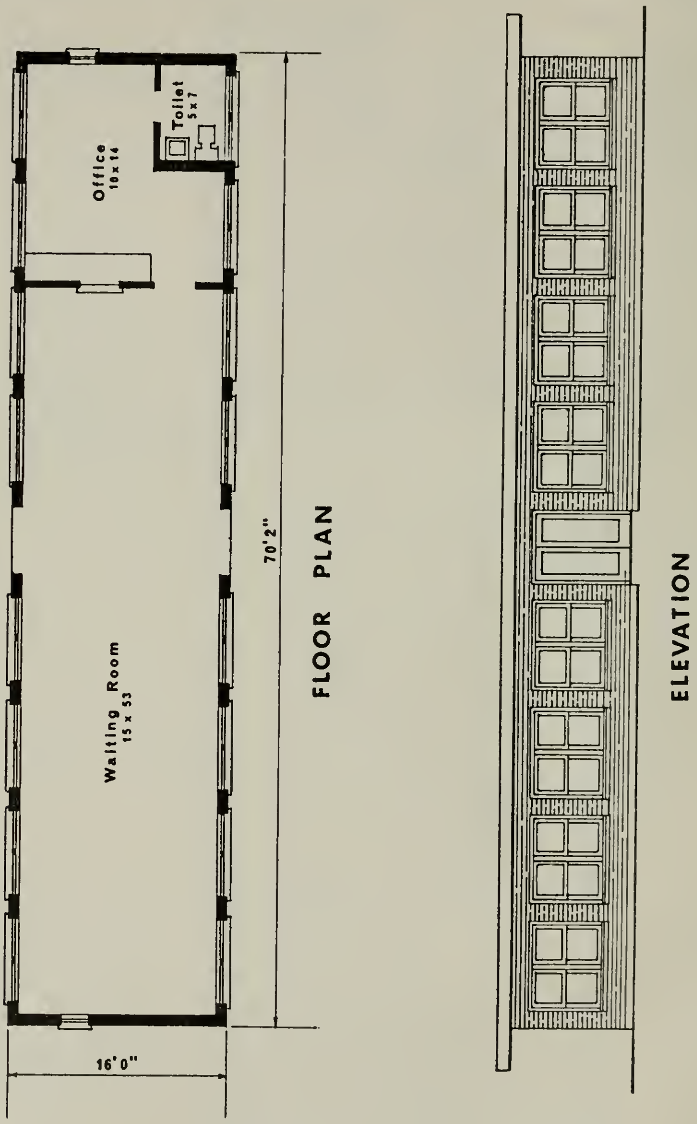
Fig. 11



PASSENGER STATION
MILWAUKEE, WISCONSIN

Fig. 12

FIRST FLOOR PLAN



PASSENGER STATION
ROSELLE, ILLINOIS

Fig. 13

Manual Recommendations

Committee 8—Concrete Structures and Foundations

Report on Assignment B

Revision of Manual

R. J. Brueske *(chairman, subcommittee)*, D. H. Dowe, T. L. Fuller, F. A. Kempe, L. M. Morris, C. H. Splitstone, J. R. Williams, W. R. Wilson.

Your committee submits for adoption the following recommendations with respect to Chapter 8 of the Manual:

Pages 8–2–1 to 8–2–27, Incl.

SPECIFICATIONS FOR DESIGN OF PLAIN AND REINFORCED CONCRETE MEMBERS

On page 8–2–1, delete present Article 4, Pier Protection, and substitute the following:

4. Pier Protection

Piers supporting bridges over railways and located within 25 ft of the centerline of a railroad track shall be of heavy construction or shall be protected by a reinforced concrete crash wall extending to not less than 6 ft above top of rail. When two or more light columns compose a pier, a wall at least 2 ft thick shall connect the columns. When a pier consists of a single column, it shall be protected by a crash wall parallel to the track. The wall shall be at least 2 ft 6 in thick and extend for a distance of at least 6 ft from both sides of the column. The face of the crash wall shall extend a distance of at least 6 in beyond the face of the column on the side adjacent to the track and shall be anchored to the column and footings with adequate steel reinforcement.

On page 8–2–1, add the following new Art. 5 to Sec. A:

5. Design of Public Works Projects

(a) The design, plans, special provisions and specifications for railroad bridges to be built as a public works project and paid for with public funds administered by a public agency shall be prepared by the engineering staff of the railroad involved or by a consulting engineer whose selection has been mutually approved by the railroad and the public agency. The intention of this requirement is that if a consultant is selected, it shall be one who is familiar with the design of railroad bridges, and particularly with the special requirements and operating conditions of the railroad concerned so that the time involvement of the railroad's engineering staff will be minimized.

(b) If a consulting engineer is engaged, the contract for his services may be administered by the public agency or by the railroad if it so desires. In either case, the technical aspects of the work of the consulting engineer shall be under the direction of the railroad and the final plans and specifications must meet with the approval of the railroad.

Pages 8–3–1 to 8–3–16, incl.

SPECIFICATIONS FOR DESIGN OF SPREAD FOOTING FOUNDATIONS

Delete present material on these pages, substituting therefor the following rewritten specifications.

3.0 SPECIFICATIONS FOR DESIGN OF SPREAD FOOTING FOUNDATIONS

3.1 DEFINITIONS

3.1.1 General

A spread footing is a structural unit by means of which a load is transferred and distributed to the underlying soil or rock at a pressure consistent with the requirements of the structure and the supporting capacity of the soil or rock.

3.1.2 Classification

3.1.2.1 Spread footings may be classified in accordance with their structural arrangement as follows:

- a. An individual column footing, which supports a single column or isolated load.
- b. A wall footing or continuous footing, which supports a wall.
- c. A combined footing, which supports more than one column.
- d. A raft or mat footing, which supports all the columns in a structure or in a large portion thereof.

3.1.2.2 Spread footings may be classified in accordance with their depth and dimensions, as follows:

- a. Shallow footings, for which the depth of foundations D_f, defined as the minimum vertical distance from the base of the footings to the surface of the surrounding ground or floor, does not exceed the least width, B, of the footing. (See Fig. 1).
- b. Deep footings, for which the distance D_f is greater than B.

3.1.2.3 Spread footings may be classified with respect to the subsurface materials from which they derive their support, as follows:

- a. Footings on granular material, or non-plastic silt.
- b. Footings on saturated clay or plastic silt.
- c. Footings on unsaturated clay or silt.
- d. Footings on non-homogeneous deposits.
- e. Footings on rock.

3.2 INFORMATION REQUIRED

3.2.1 Field Survey

All available information shall be furnished, in the form of a plat or topographic map, in order to adapt the structural requirements to the field conditions. The location of underground utilities, the location and dimensions of existing foundations, and the location of existing roads, tracks, or other structures shall be indicated. In connection with footings for river crossings, the records of normal high water, low water, flood-water level, depth of scour, stream velocities, and alignment of the stream shall be provided.

All information available concerning the nature of the foundations of neighboring structures on similar materials, and of the settlement and behavior of these

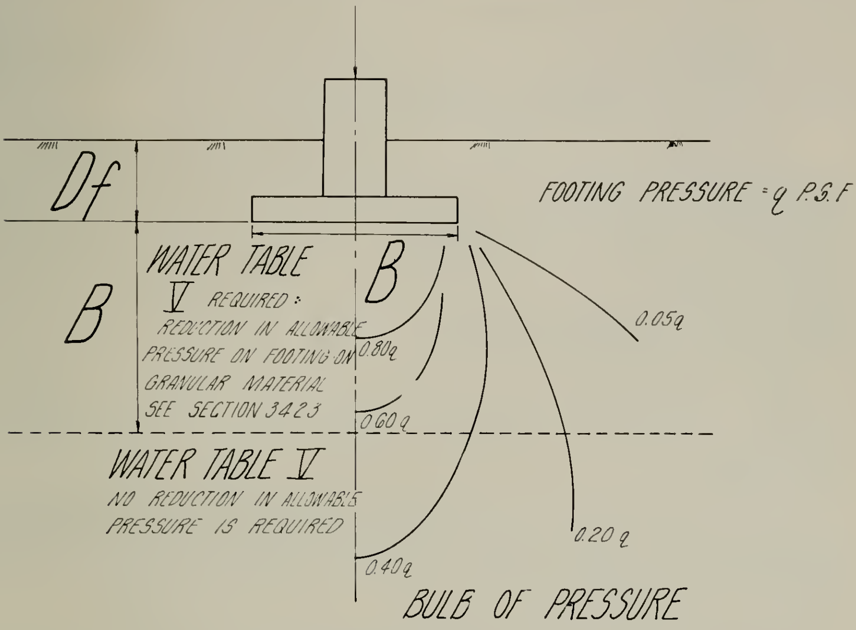


Fig. 1—Factors affected by depth.

foundations, shall be assembled and condensed as a guide to the judgment of the engineer in the design of the new structures.

3.2.2 Controlling Dimensions

Information shall be assembled concerning the proposed arrangement of the columns, piers, or equipment to be supported; the depths of basements, tunnels, and other excavations; the elevation of the surface of filled areas; and all other factors that may affect or be affected by the construction.

3.2.3 Loads

The loads to be supported by the foundations shall be indicated. These shall be subdivided into the following categories:

a. Dead load.
b. Normal live load, defined as the live load that is likely to be transmitted to the foundation throughout the greater portion of the useful lifetime of the structure.
c. Maximum live load, defined as the greatest live load that may be anticipated at any time during the lifetime of the structure.
d. Longitudinal and lateral forces.
e. Snow load.
f. Ice load.
g. Earthquake load.
h. Wind load.

i. Hydrostatic loads, including buoyancy and the forces exerted by flowing water.
j. Area load, defined as any load transmitted to the supporting soil or rock, by the addition of fill or other structures to the area.
k. No impact shall be considered in the design of a footing.
l. Vibratory loads to footings on granular material shall be considered.

An estimate shall be made of the duration of each loading, since the settlement of some types of subsurface materials depends upon the proportion of the total time during the load or loads are active.

The character, frequency, and amplitude of any vibratory loads shall be noted, for further analysis.

3.2.4 Character of Subsurface Materials

3.2.4.1 General

Pertinent supplementary data with respect to local geological or foundation conditions, including aerial photographs and agricultural soil maps, should be assembled if available. Data concerning changes in groundwater level should also be investigated.

The data concerning subsurface materials shall be assembled in suitable graphical form, such as cross sections through the various deposits, showing the probable arrangement and sequence of lenses or strata, the pertinent physical properties of each element of the deposit, and the location of the groundwater table.

3.2.4.2 Field Investigation

The nature and extent of the various formations of soil and rock beneath the site and the depth to ground water shall be determined by means of test borings or probes and physical tests of a type and to an extent appropriate to the character and importance of the structure and the nature of the subsurface materials. The borings shall be made in accordance with the AREA recommendations in Part 1, Chapter 1 of the Manual. Load tests and other physical tests that may be considered necessary on the basis of the results of the borings shall be performed in such manner as to provide information for soil bearing capacity, settlement determinations, and other significant information pertinent to the particular conditions at the site.

For major structures, at least one boring should, if practicable, extend into bedrock. Borings should at least extend to a depth equal to three times the least footing width plus the depth of the footing from the ground surface. For major structures on cohesive soils undisturbed samples should generally be recovered for laboratory testing. The recovery of undisturbed samples in granular soil has not proven satisfactory.

3.2.4.3 Depth of Frost

The maximum depth of frost penetration shall be determined, usually on the basis of local experience and records. Similarly, in regions of excessively swelling or shrinking soils, the depth shall be determined within which significant volume changes occur as a result of seasonal variations in moisture content.

3.3 DEPTH OF BASE OF FOOTINGS

3.3.1 Selection of Tentative Depths

On the basis of the data concerning the subsurface materials, tentative elevations for the bases of the footing should be selected. Unless special provisions are made, the depth shall not be less than the depth of front penetration, scour, or, in expansive clay subsoils, less than the thickness of the zone of significant volume change of the subsoil due to seasonal moisture variations.

3.3.2 Revision of Depths of Footings

After the preliminary depths have been selected, the allowable soil pressure shall be determined and the sizes of the footings proportioned to the pressures. If the resulting design is not feasible or economical, similar studies shall be made for footings established at other depths until the most suitable and economical arrangement is determined. In considering the relative economy of footings at various levels, the cost and difficulty of excavation below groundwater level in previous soils shall be taken into account. The economy and suitability of other types of foundations, such as piles or caissons, shall also be considered.

3.4 ALLOWABLE SOIL PRESSURE

3.4.1 Definition

The allowable soil pressure for footings supported by rock or soil shall be taken as the smaller of the following two quantities:

a. The safe net soil pressure, defined as the ultimate soil pressure Q_d at which the supporting material will fail beneath the footing, less the existing soil pressure, divided by an appropriate factor or safety. For building foundations, the safe net pressure shall provide a factor of safety of three against dead load plus normal live load and snow load, and a factor of safety of two against dead load plus maximum live load, snow load, and wind or other transient loads. For bridge foundations, the safe soil pressure shall provide a factor of safety of three against dead load plus maximum live load and centrifugal force, and a factor of safety of two against the sum of these same forces plus wind load, traction load, ice load, and other transient loads.

b. The allowable pressure for settlement, defined as the maximum pressure to which the footings of the structure may be subjected without producing excessive settlement or excessive differential settlement of the structure. This settlement consists of two stages: (a) Initial settlement called "contact settlement" (b) "consolidation" which occurs over an extended period.

Settlement caused by vibratory loading shall be considered as a special investigation, and shall not be undertaken as part of the normal design.

The soil pressures are to be considered as net pressures; that is, they represent the pressure at the base level of the footing in excess of the pressure at the same level due to the weight of the surrounding soil immdiately adjacent to the footing.

3.4.2 Shallow Footings on Granular Material

3.4.2.1 General

The safe soil pressure for a shallow footing on granular material depends on the width B of the footing, the depth of foundation D_f, the relative density of the material, and the position of the groundwater table.

The location of the present and/or future ground water level will noticeably affect the bearing capacity of the footing. Due consideration should be given to the future groundwater level.

Vibrational loads can cause severe settlement of a footing founded on loose to medium granular soils. If future construction in the immediate area will require pile driving, vibratory compaction of sub-soil, or other vibrations, then consideration should be given to a more extensive vibratory analysis.

3.4.2.2 Unsaturated Sand

The allowable load on unsaturated sand, based upon settlement and with a minimum factor of safety of three, can be estimated by use of Fig. 2. If D_f is less than 2 ft, a lower allowable load will be obtained and if D_f is greater than 2 ft, a greater allowable load may be possible. In these cases a more complete analysis is required, as provided in Art. 3.4.3.

3.4.2.3 Saturated Sand

For saturated sand, the vertical and horizontal effective stress is reduced approximately in half. Therefore the allowable load, determined by settlement, should be reduced by 50% if the water table is at the elevation of the footing, and by 0% for the water table at a depth of B below footing. The engineer may interpolate for intermediate values.

3.4.3 Deep Footings on Granular Material

The sage soil pressure for deep footings is a problem requiring considerable investigation if high concentrated loads are to be supported, such as is found in the case of a drilled shaft. These footings will always be able to support more load than a shallow footing for the same strength and depth of soil encountered below the footing. For design see such works as G. G. Meyerhoff "Ultimate Bearing Capacity of Foundations" *Geotechnique* (1951) or Terzaghi and Peck *Soil Mechanics in Engineering Practice* (1968).

3.4.4 Shallow Footings on Saturated Clay and Saturated Plastic Silt

3.4.4.1 Strength Characteristics

The ultimate soil pressure for shallow footings on saturated clays or clayey soils depends on the width B, the length L, the depth D_f of the footing below the surface and on the unconfined compressive strength q_u of the clay. The ultimate soil pressure q_d for a rectangular footing may be determined by means of equation:

$$q_d = 2.5 q_u \left(1 + \frac{B}{5L}\right)\left(1 + \frac{D_f}{5B}\right)$$

In this quotation, q_d and q_u are expressed in the same units. The value of q_u shall be taken as the average unconfined compressive strength of the clay within a depth B below the base of the footing; provided, however, that the strength of the clay does not decrease significantly with increasing depth below the footing. In the event that soft material underlies stiffer material, a special investigation of the bearing capacity of this level shall be undertaken. The correct factor of safety shall be used in order to obtain an allowable bearing pressure.

3.4.4.2 Settlement Characteristics

For loads located on or above medium clays, (q_u below 2.0 tons per sq ft) a settlement analysis should generally be undertaken. In certain cases, large settlements will occur by consolidation of an underlying layer under very small additional loads. If any doubt exists concerning the consolidation characteristics of the soil, one or more consolidation tests should be undertaken. Settlement by "consolidation" of underlying clay layers can be many times the initial "contact settlement." Both the consolidation and contact settlements can be estimated by laboratory analysis.

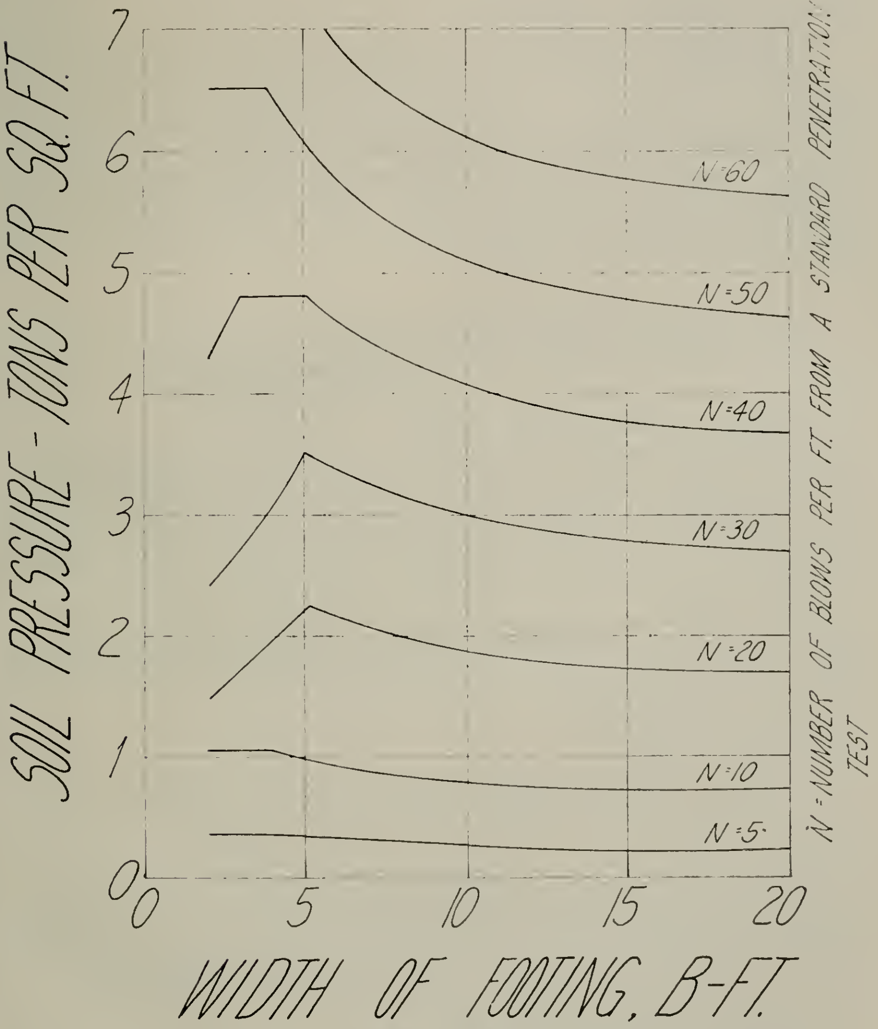


CHART BASED ON WATER TABLE NOT CLOSER THAN B BELOW BASE OF FOOTING, AND Df = 2 FEET

Fig. 2—Soil pressure corresponding to 1-inch settlement of footings on granular materials and having a minimum factor of safety of 3.

The effect of subsidance to drainage of the soil shall be considered in the design of the structure.

3.4.5 Deep Footings on Saturated Clay

3.4.5.1 Strength Characteristics

The ultimate soil pressure for deep footings supported on saturated clayey soils shall be determined by the same procedures as the ultimate capacity determination for deep footings on granular soils. However, when the depth of the footing is greater than two times its least dimension, the ultimate bearing capacity will be equal to or greater than 4.5 q_u. A detailed analysis is necessary in order to more accurately determine the ultimate capacity of a deep footing. A designer should investigate this capacity if a greater allowable load is needed. The theory is the same as referenced under Art. 3.4.3.

3.4.5.2 Settlement Characteristics

The settlement of a structure supported by deep footings shall be investigated by the same procedures as those for shallow footings on such materials.

3.4.6 Footings on Unsaturated Silts and Clays

Accurate determination of the bearing capacity of such soils at the present state of knowledge is often not possible. Due to the existence of hairline cracks in the soil structure, and unknown pore-air pressures, an extensive field investigation may be required. Each structure will have a different solution. Careful evaluation is necessary in order to arrive at a satisfactory footing design. A rise in the groundwater table will reduce the allowable capacity and complicate the analysis.

Where loadings on footings are light, or in the case of a floor slab, roadway, walks, or other similar lightly loaded areas, due consideration to swelling of a clay soil shall be given. This may be especially important if the percent of soil less than 0.001 mm is greater than 15%.

3.4.7 Footings on Rock

Soft, intact rocks with insignificant joints or bedding planes, such as some shales or siltstones, may be regarded as stiff to hard clays, and design of footings on these materials may be based on the procedures applicable to hard clayey materials.

The allowable pressure on formations of rocks of greater intrinsic strength is commonly determined by such structural features or defects as joints, bedding planes, cavities, and faults, but the design shall be based on experienced judgment formed after a detailed study of the character and defects of the formation.

3.4.8 Footings on Non-Homogeneous Deposits

Footings established above stratified or other non-homogeneous formations shall be proportioned on the assumption that the most unfavorable condition disclosed by the subsurface exploration may be present under the most heavily loaded footings, unless detailed information is obtained concerning the actual conditions beneath each footing.

Subsoil of this type requires extensive knowledge and investigation in order to obtain an accurate solution. However, in many cases using the above assumption in order to simplify the solution is satisfactory.

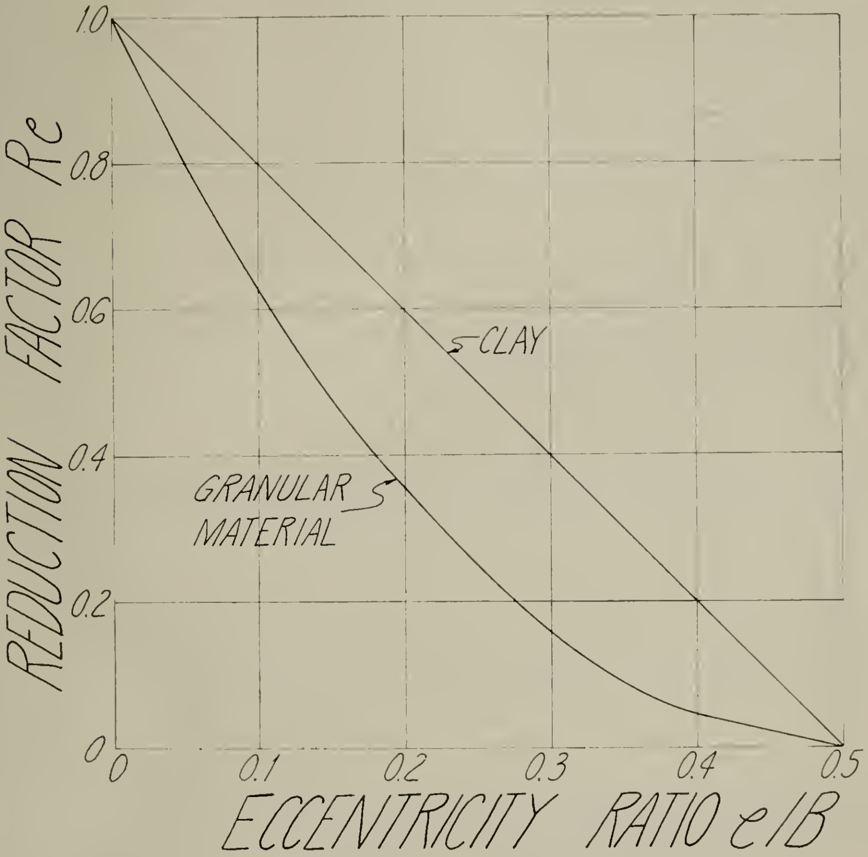


Fig. 3—Correction for eccentricity of load.

3.4.9 Footings on Granular Soils with Cohesion

Many soils fit this category and an accurate analysis can be carried out. The investigation must be undertaken without the use of the simplifying assumptions made for granular or cohesive soils, and more extensive laboratory information is required. Triaxial shear tests are required for this analysis.

At times, it will be satisfactory to assume the soil alternately only granular or cohesive and use the lower value for allowable pressure.

3.4.10 Allowable Pressure on Footings with Eccentric or Inclined Loads

The capacity of a footing under eccentric and inclined loads can be determined according to recognized theory (i.e., as set forth by G. G. Meyerhoff).

The capacity of the footing can be approximated by use of the two graphs in Figs. 3 and 4. The allowable bearing capacity must be multiplied by the "Reduction Factor" obtained from these graphs. A more satisfactory design can be obtained by more complete analysis.

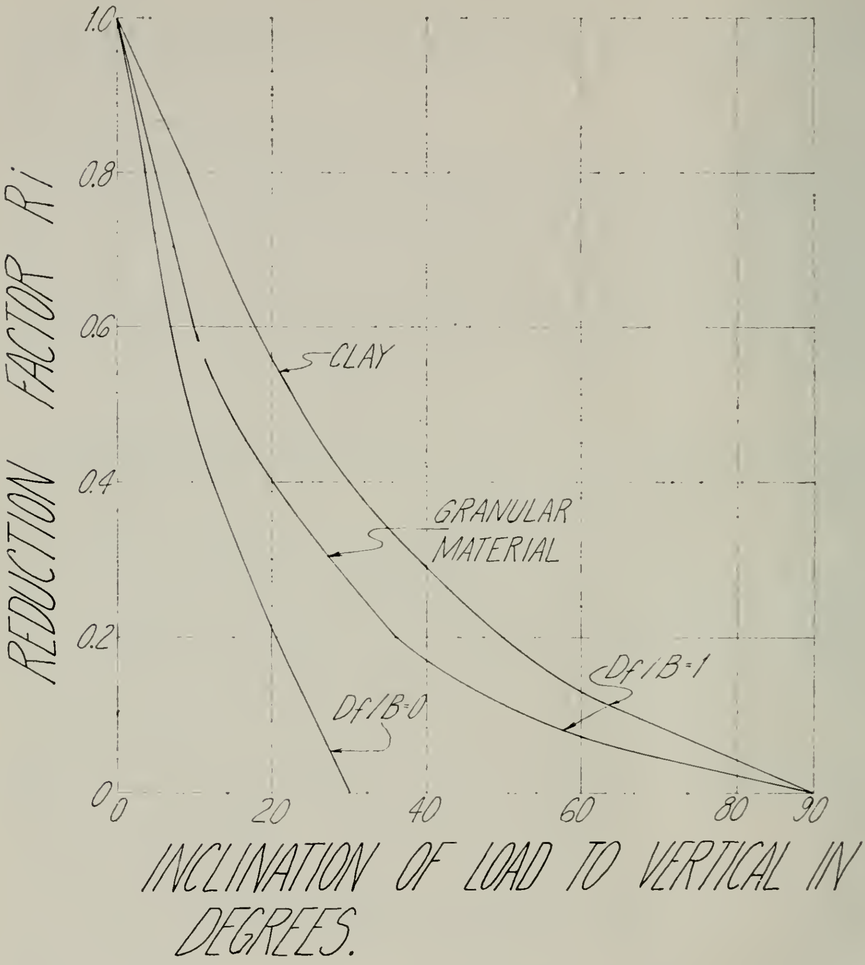


Fig. 4—Correction for inclination of load.

3.5 FOOTING STRESSES

3.5.1 Loads Eccentric In One Direction Only

For computation of the stress within the footing itself, the pressures on the foundation may be calculated by the following relationships (see Fig. 5); however it is desirable, if possible, to proportion the footing for an equal pressure distribution:

A more detailed study may be required for a flexible, combined, or mat footing. In actual practice the pressure distribution may vary materially from this ideal distribution. The correct distribution of the reaction is dependent upon the rigidity of the footing, distribution of the loading, characteristics of the soil, and the factor of safety.

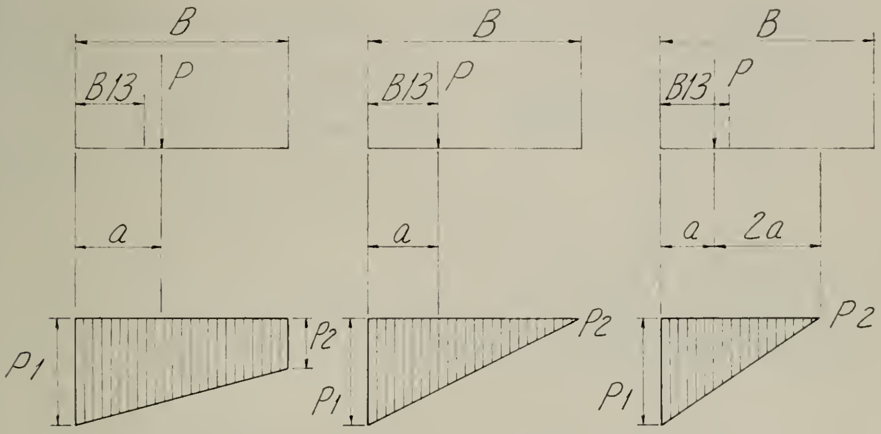


Fig. 5—Soil pressures for design of footings under eccentric loading—to be used only for stresses within the footing. For allowable soil pressures, use Fig. 3 and Fig. 4.

3.5.2 Loads Eccentric in Two Directions

If the footing is eccentrically loaded in two directions, the pressure for computation of stresses in the footing can be determined by use of the charts, Fig. 6.

3.6 FIELD CONDITIONS

3.6.1 Modification of Design

If excavation discloses soils or soil conditions different from those upon which the design of the footings has been based, the design shall be altered as necessary. The plans for the footing should indicate the type of soil and soil pressure upon which the design is based.

3.7 DETAILS OF DESIGN

3.7.1 Reinforcement

Wherever the concrete of a reinforced footing is in contact with the soil, steel reinforcement shall be provided with a cover of not less than 3 in. If the concrete is placed against a seal coat or against steel sheeting that is to remain in place, the cover shall be not less than 2 in.

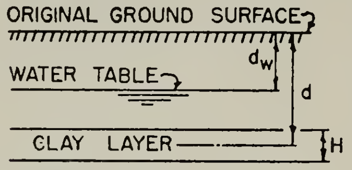
3.7.2 Footings at Varying Levels

If the footings for two adjacent parts of a structure are established at different levels, the difference in elevation of the bases of adjacent footings, divided by the least horizontal clear distance between the footings, shall not exceed a value appropriate to the characteristics of the subsoil, and in general should not exceed 1.0. An increased load on the lower footing will result from this configuration.

3.7.3 Drainage

Unless underwater construction is specified, surface water or groundwater shall not be permitted to accumulate in excavations for footings. Such water shall be conducted to sumps located outside the boundaries of the footing and removed. If the

1. DETERMINE NATURAL WATER CONTENT W OF CLAY (% OF DRY WEIGHT)
2. DETERMINE INCREASE OF PRESSURE Δp (lb/sq ft) AT MID-HEIGHT OF CLAY LAYER
3. DETERMINE EXISTING INTERGRANULAR OVERBURDEN PRESSURE p_0 (lb/sq ft):



IF WATER TABLE IS ABOVE ℄ OF CLAY LAYER $p_0 = 62d_w + 53d$

IF WATER TABLE IS BELOW ℄ OF CLAY LAYER $p_0 = 115d$

d_w, d & H ARE EXPRESSED IN ft

4. DETERMINE $R = \Delta p / p_0$
5. DETERMINE A FROM CURVE 1 AND VALUE OF w
6. DETERMINE B FROM CURVE 2 AND VALUE OF R
7. COMPUTE SETTLEMENT $S(\text{ft}) = H \cdot A \cdot B$

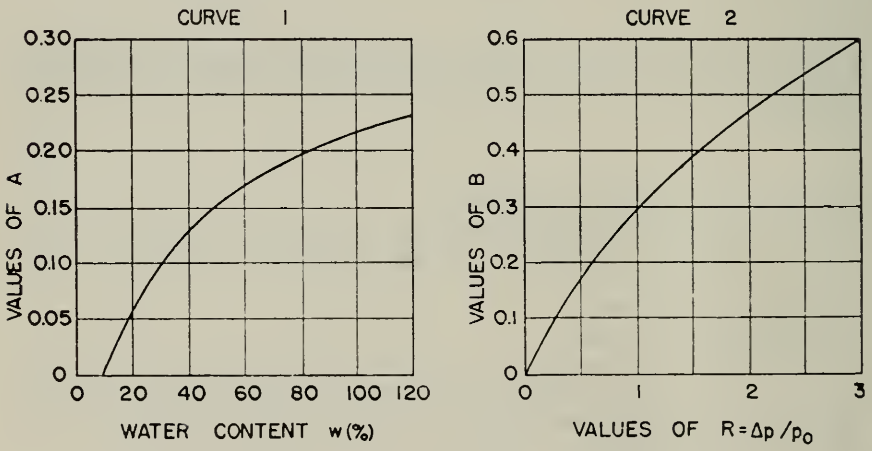


Fig. 6—Upper limiting value of settlement due to soft clay layer.

water cannot be handled by this procedure, groundwater lowering should be accomplished by well points, a tremie seal coarse, or other appropriate means.

3.7.4 Treatment of Bottom of Excavation

Care shall be exercised to prevent disturbance of the materials at the bottom of the excavation by equipment or by the feet of the workmen. The bottom 2 in of concrete in the footing shall be neglected for strength calculations.

On soft clayey or silty soils a working platform or mud coat of lean concrete, from 2 to 3 in. in thickness, is recommended if disturbance is probable. Otherwise, final excavation of the last 3 to 6 in above grade should be deferred until immediately before placement of the reinforcement. The concrete in a working platform or mud coat shall not be considered as contributing to the strength of the footing.

If a tremie seal is to be placed to permit dewatering of the cofferdam for a pier, the thickness of the seal shall be adequate to withstand the upward pressure of the water beneath the seal at the time of dewatering. This uplift force shall be determined by a rational analysis.

3.7.5 Stresses

Concrete and steel allowable stresses shall be in accordance with Plain and Reinforced Concrete Members, Part 2 of this chapter.

3.7.6 Information on Drawings

Design drawings shall indicate the allowable soil pressure, type of soil, grade of the reinforcing steel, strength of concrete, minimum cement factor, and other pertinent data.

Your committee also submits for adoption the following recommendation with respect to Chapter 29 of the Manual:

Delete present Manual material pertaining to asphaltic panels beginning on page 29–2–5 and ending on page 29–2–7, substituting therefor the following revised material on asphaltic panels.

g. *Asphaltic Panels in a Layer or Layers (Engineer's Option) Not Less Than ¾ Inch Thick*

Asphaltic panels shall meet the following requirements.

1. Manufacture
    1.1 Each panel is formed as a 5-layer member, including a core of a selected blend of asphalt and inorganic mineral filler particles, a bottom reinforcing cover of asphalt-saturated felt and on the top, a cover of asphalt-saturated felt or fibre glass mat that is weather coated and has bond breaking film or coating.
    1.2 Asphalt and inorganic mineral filler particles shall be blended to form the core, with the asphalt forming the matrix of the blend to carry the particles. The mineral filler particles function to impart increased density and enhance stiffness and body in the core.
    1.3 The inorganic mineral filler particles constitute an aggregate bound in the asphalt matrix which will permit points of ballast rock to penetrate a short distance into the core to secure a good seating position. The aggregate will then resist further penetration and will support the ballast rock.

2. Workmanship
    2.1 The protection course shall be free from defects affecting its serviceability and appearance; it shall have straight edges and square corners.

3. Properties
    3.1 Asphaltic panels shall have the dimensions specified or shown on the plans. Tolerance of ±1/16 inch in thickness, ±⅛ inch in width and ±¼ inch in length shall be permitted.
    3.2 Weight per sq ft minimum (0.375 inch thickness) ....2.60 lb per sq ft
    3.3 Weight per sq ft minimum (0.50 inch thickness) ....3.50 lb per sq ft
    3.4 Water absorption, max., ASTM D 545 (10) .. 1.0%
    3.5 Thickness of asphalt weather-coating, rivuleted average, inches .... 0.020 minimum
    3.6 Asphalt saturated felt liners .... Max. 15 lb per 100 sq ft after saturation
    3.7 Asphalt content, core ASTM D 147 (3a) (4a) . 50–60% by weight

3.8 Inorganic mineral filler particle content, core ASTM D 147 (3a) (4a) .... Min 25% by weight

3.9 Resistance to decay, ASTM E 154 (10) (11) . No effect

3.10 Flexibility .... No cracking or breaking

3.11 Brittleness at 39°–43°, ASTM D 994 (7.2) ... No cracking or shattering

3.12 Heat distortion ASTM D 994 (7.1) .... 0.3125 inch max.

3.13 Mineral Filler

3.13.1 Carefully selected and graded inorganic mineral filler particles shall be blended with the asphalt to form the matrix of each panel.

3.14 Weathercoating

3.14.1 Asphaltic weathercoating shall be flowed on the exterior top surface of the protection course. This coating shall be rivuleted in surface, shall be of sufficient thickness to provide complete dimensional stability to the material, when stored outdoors in direct sunlight. A suitable bond breaking film or coating shall be applied, to function as a release sheet. During installation, the asphalt-saturated felt side shall be placed against the membrane waterproofing; the side with the bond breaking film or coating shall be exposed to the ballast rock.

3.15 Resistance to Penetration, Dynamic Loading

3.15.1 The degree of resistance to penetration, when tested in accordance with ASTM D 1883-67, modified to a 1-inch metal penetration piston, shall meet the following requirements:

Temperature, °F	*Dynamic Load, Lb*	*Penetration, In.*
100	225	0.10 maximum
77	350	0.10 “
40	600	0.10 “

4. Inspection

4.1 Sample from each lot shall be examined for appearance, straightness of edges and squareness of corners, and measured for width and length. They shall be calipered at four standard points each, with a micrometer having flat bearing surfaces at both contact points of not less than ¼ inch diameter. The average of the readings shall be considered the thickness of the protection course.

5. Flexibility Test

5.1 Three specimens 3 inches by 12 inches shall be conditioned at 77° ±5° F for not less than 2 hours immediately prior to being subjected to test.

5.2 Place specimen with the 12-inch dimension perpendicular to and centered over the axis of a horizontal cylinder having a diameter of 19 ± 1 inches.

5.3 Clamp one end and grasp the other end of the samples and bend around the cylinder at the uniform rate to complete bend in 60 ± 10 seconds until the specimen is in full contact with the surface of the cylinder.

5.4 Examine for any cracking or breaking of the sample.

Manual Recommendations

Committee 9—Highways

Report on Assignment B

Revision of Manual

J. E. Spangler *(chairman, subcommittee)*, J. M. Bates, L. T. Cerny, C. A. Christensen, J. W. Cruikshank, F. Daugherty, R. V. Gilbert, H. D. Hahn, C. I. Hartsell, D. P. Insana, P. G. Jefferis, Jr., R. V. Loftus, R. F. MacDonald, G. U. Mentjes, J. C. Miller, R. E. Skinner, David Veitch, W. E. Webster, Jr., C. H. Worboys, K. E. Wyckoff.

Your committee, by letter ballot, has approved revisions of Part 1 of Chapter 9 of the AREA Manual. The revisions reflect a need felt by the committee for additional data, including drawings, on the subject of various types of highway-railway grade crossings.

The revisions approved by your committee are now submitted for adoption and publication in the Manual. The specific revisions are as follows:

Pages 9–1–2 and 9–1–3

GENERAL SPECIFICATIONS FOR HIGHWAY GRADE CROSSINGS OVER RAILROAD TRACKS

There are no changes in the text on these two pages proposed at this time, but in line with the program to decimalize chapters in the AREA Manual, it is proposed to number the title and Article headings as follows:

Add 1.1 ahead of title, "General Specifications for Highway Grade Crossings over Railroad Tracks."

Renumber present Articles 1 through 9 as Articles 1.1.1 through 1.1.9, respectively.

Pages 9–I–4 and 9–1–5

SPECIFICATIONS FOR THE CONSTRUCTION OF BITUMINOUS CROSSINGS

Add 1.2 ahead of title, "Specifications for the Construction of Bituminous Crossings."

Renumber present Articles 1 through 5 as Articles 1.2.1 through 1.2.5, respectively.

Add the following sentence at the end of Article 1.2.5:

"Shown in Fig. 1 is a crossing meeting these specifications, using timber headers on the gage and outer sides of the rail."

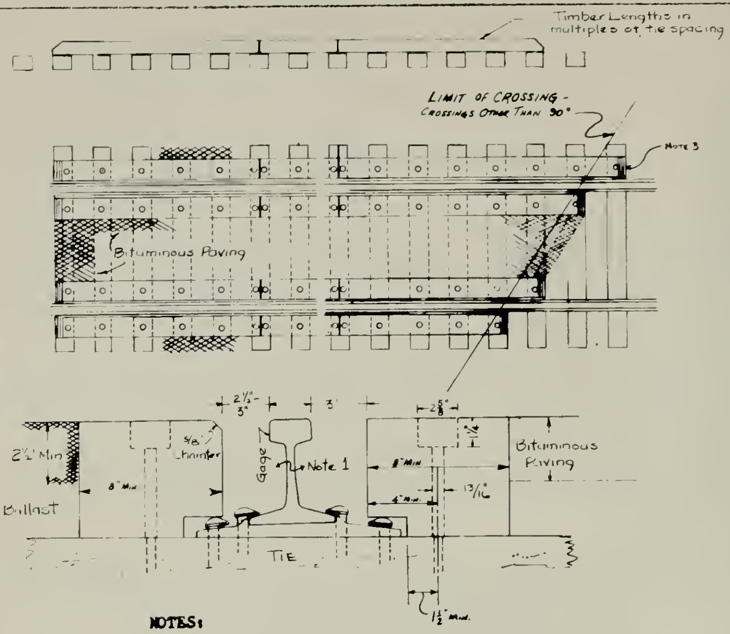
Renumber present Article 6 as Article 1.2.6, and present Paragraph (a) as 1.2.6.1.

Add 1.2.6.1.1 at "Paint Coat," 1.2.6.1.2 at "Binder Course," 1.2.6.1.3 at "Wearing Surface," and 1.2.6.1.4 at "Seal Coat."

Replace (b) with 1.2.6.2.

Add 1.2.6.2.1 at "Wearing Surface."

Add Fig. 1 presented herewith.



NOTES:

Note 1: Spaces between rail and headers may be filled with snugly-fitting timber fillers or mastic material.

Note 2: Each timber shall be securely spiked down at its ends and to at least to every other tie. Timbers shall be bored for drive spikes and dowels to prevent splitting. Drive spikes, lag screws or twist dowels shall be 3/4" diameter and shall have a holding length of at least 5" in the tie. Only one lag screw or twist dowel in every other tie for each plank shall be required. Planks shall be bored for lag screws and shall be countersunk for the washers and lag screw heads. Where twist dowels are used, the planks shall be bored with bits having a diameter which will assure full holding power of the dowel.

Note 3: The outer end of each timber on each end of the crossing shall be beveled not more than 45 degrees with the horizontal with a minimum end thickness of one inch.

Fig. 1—Construction plan, bituminous crossing.

Pages 9–1–6 and 9–1–7

SPECIFICATIONS FOR THE CONSTRUCTION OF WOOD PLANK CROSSINGS

Add 1.3 ahead of title "Specifications for the Construction of Wood Plank Crossings."

Renumber present Article 1 as Article 1.3.1. Add the phrase "as shown in Fig. 2" at end of first sentence of this Article.

Renumber present Articles 2 through 4 as Articles 1.3.2 through 1.3.4, respectively. Under 1.3.4, replace (a) with 1.3.4.1 and (b) with 1.3.4.2.

Renumber Article 5 as Article 1.3.5; add 1.3.5.1 at paragraph beginning "Type A Crossing," 1.3.5.2 at paragraph beginning "Type A Flangeway," 1.3.5.3 at paragraph beginning "Type B Crossings," and 1.3.5.4 at paragraph beginning "Type B Flangeway."

Replace last three sentences of Paragraph 1.3.5.2 with the following:

"The planks adjacent to the rail should be set back 2½ to 3 in from each side of the ball of the rail to facilitate renewal of the rails in the crossing without the necessity of removing the adjacent planks on each side. These spaces shall be filled with some mastic material in order to close up these openings. This mastic material shall be such that it will keep water from getting down through the flangeway to the ties, and yet be readily removable with a pick if it should be necessary to renew the rail. Where vehicular traffic is heavy, snugly fitting wood fillers should be installed on both sides of the rail to reduce the impact transmitted to the lower part of the rail and its fastenings to the tie as shown in Fig. 2. The top surface of each plank will be ¼ in below the plane of the tops of the rails."

Replace last sentence of Paragraph 1.3.5.4 with the following:

"The planks adjacent to the rail should be set back 2½ to 3 in from the ball of the rail, similar to specifications under Type A crossings."

Renumber present Articles 6 through 8 as Articles 1.3.6 through 1.3.8.

Add Fig. 2 presented on page 222.

Pages 9–1–8 and 9–1–9

SPECIFICATIONS FOR THE CONSTRUCTION OF PREFABRICATED SECTIONAL TREATED TIMBER CROSSINGS

Add 1.4 ahead of title, "Specifications for the Construction of Prefabricated Sectional Treated Timber Crossings."

Renumber Article 1 as Article 1.4.1. Add the phrase "as shown in Fig. 3" at end of first sentence of this Article.

Renumber Articles 2 through 8 as Articles 1.4.2 through 1.4.8, respectively.

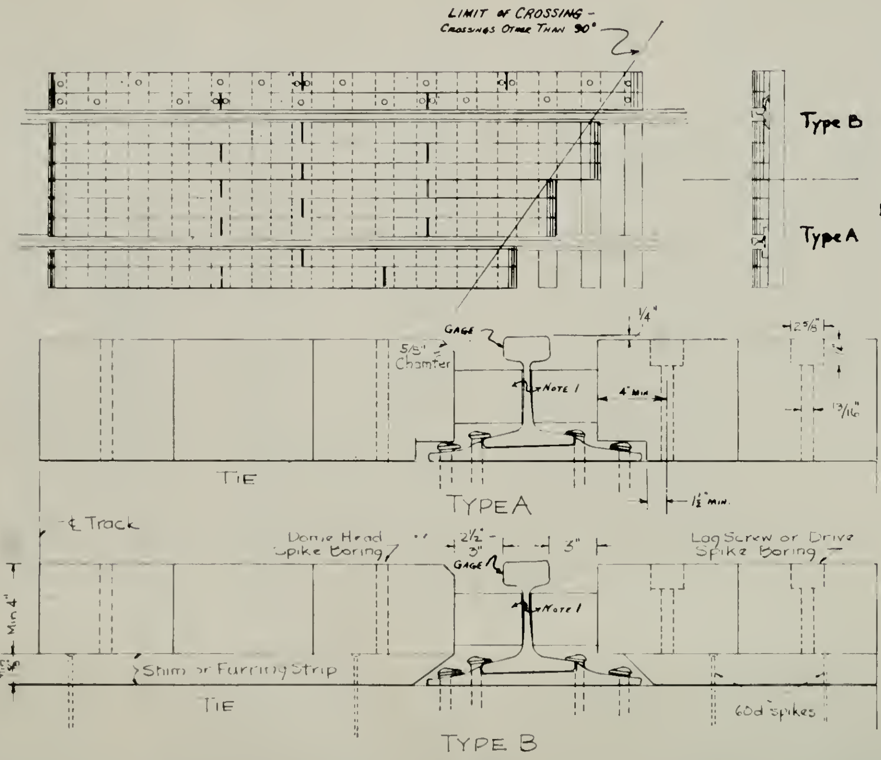
Add Fig. 3 presented on page 223.

Pages 9–1–10 and 9–1–11

SPECIFICATIONS FOR THE CONSTRUCTION OF TRACKS IN A PAVED AREA

Add 1.5 ahead of title, "Specifications for the Construction of Tracks in a Paved Area."

Renumber present Articles 1 through 7 as Articles 1.5.1 through 1.5.7, respectively.



NOTES:

Note 1: Spaces between rail and headers should be filled with snugly-fitting timber fillers as shown or mastic material. See Page 9-1-7, 5.

Note 2: Lag screw or Drive Spike Boring and Dome Head spike boring are shown as alternates.

Fig. 2—Construction plan, wood plank crossing.

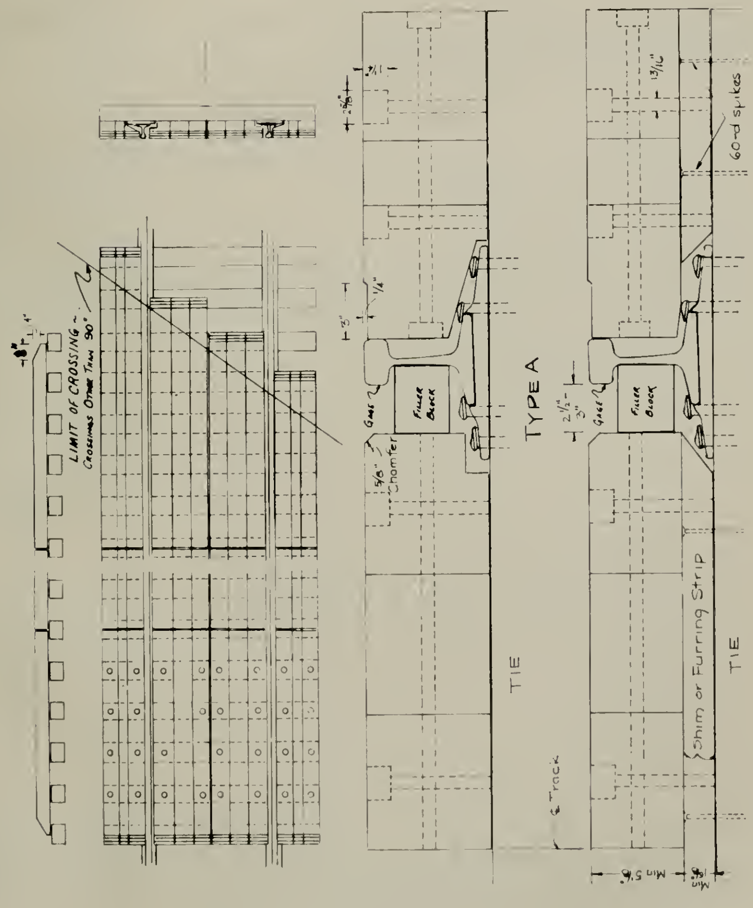


Fig. 3—Construction plan, prefabricated sectional treated timber crossing.

Manual Recommendations

Committee 11—Engineering Records and Property Accounting

Report on Assignment 3

Office and Drafting Practices

W. C. Kanan *(chairman, subcommittee)*, P. J. Beyer, J. M. Bourne, R. H. Campbell, P. J. Hendricksen, J. J. Hoolahan, J. W. Kelly, J. G. Kirchen, J. L. Manthey, M. F. McCorcle, G. L. Muchow.

Your committee submits for adoption the following recommendations with respect to Chapter 11, Part 21 of the Manual:

Add new instructions and form following Manual page 11–2–48.

STATUS OF AFE PROJECTS

1. Purpose of Form

To provide a convenient form to report on the progress toward physical completion of Authorities for Expenditures.

2. Instructions for Use of Form

The Status of AFE Projects Form is designed for use by each Division or Department having AFE activity. The suggested size of form is 8½ x 11 inches.

The form should show in the upper portion the Division or Department and the date of the report (usually the last day of the month).

The body of the form should show in:

(a) The first column the AFE number.
(b) The second column the location of the project and brief description of the work.
(c) The third column the dollar amount authorized by the AFE for Capital and the dollar amount authorized for Operating. (C = Capital, O = Operating).
(d) The fourth column the date AFE was authorized.
(e) The fifth column the date work was started.
(f) The sixth column the date the installed property was placed in service.
(g) The seventh column the date the retired property was taken out of service.
(h) The eighth column the percent project is complete as of the date of report.
(i) The ninth column, remarks column; explain any unusual feature or reason for delay in progressing the work.

3. General

Depending upon the use made as a management information and/or control tool, the Status of AFE Projects report can be given wide circulation to all interested departments. For this purpose the data reporting form can easily be adapted to data-processing techniques for summarization and analysis.

The suggested format and general layout, as depicted, contains the minimum information required. The form can be modified to become general in nature, or more sophisticated to suit each individual carrier's needs.

NORTH AND SOUTH RAILROAD

Sheet ____ of ____

STATUS OF A.F.E. PROJECTS

____________ Division or Department

As of ____________

A.F.E. Number	Location and Description of Work	Amounts Authorized Capital & Operating	Date Authorized	Date Work Started	Installed Date In Service	Retired Date Out of Service	Percent Complete To Date	Remarks

Manual Recommendations

Committee 13—Environmental Engineering

Report on Assignment 4

Industrial Hygiene

R. S. Bryan, Jr. *(chairman, subcommittee),* W. D. Peters *(vice chairman, subcommittee),* R. A. Bardwell, A. E. Dulik, W. H. Melgren, T. A. Tennyson.

Your subcommittee submits for adoption and publication in the Manual the following new section for Part 4 of Chapter 13.

4.5 GENERAL ENVIRONMENTAL CONTROLS FOR SANITATION AND INDUSTRIAL HYGIENE FOR FACILITIES UNDER F.R.A. JURISDICTION

4.5.1

The provisions of the Occupational Safety and Health Act will be administered by the Federal Railroad Administration (FRA) since railroads are under the jurisdiction of the Department of Transportation. However, all references shown in Section 4.5 are from TITLE 29, CHAPTER XVII, Part 1910, SUBPART J, GENERAL ENVIRONMENTAL CONTROLS, OCCUPATIONAL SAFETY AND HEALTH STANDARDS, as published in the *Federal Register,* Vol. 37, No. 202, Wednesday, October 18, 1972. Section 4.5 is intended to be a reference guide for the material covered and the full regulations should be used for specification details. In some instances, the Department of Labor may have jurisdiction.

4.5.2 SANITATION (1910.141)

4.5.2.1 General Requirements (1910.141 (a))

(a) Housekeeping.
(b) Expectorating.
(c) Waste disposal.
(d) Rodent, insect and vermin control.

4.5.2.2 Water Supply (1910.141 (b))

(a) Potable water.
(b) Nonpotable water.

4.5.2.3 Toilet Facilities (1910.141 (c))

(a) General
    1. Separate for each sex
    2. Readily accessible
    3. Number of fixtures based on number of employees
    4. Supplies
    5. Washing facilities

(b) Construction of toilet rooms
   1. Specifications for toilet rooms

(c) Construction and installation of toilet facilities
   1. Specifications for toilet bowls

(d) Chemical closets and privies
   1. Closets and privies shall be constructed and maintained in accordance with 1910.143

4.5.2.4 Washing Facilities

(a) General—Adequate facilities for maintaining personal cleanliness shall be provided in every place of employment. These shall be convenient for the employees for whom they are provided and shall be maintained in a sanitary condition.

(b) Lavatories.

(c) Towels.

4.5.2.5 Change Rooms (1910.141 (e))

(a) Separate facilities for each sex.

(b) Drying facilities.

4.5.2.6 Retiring Rooms for Women (1910.141 (f))

4.5.2.7 Lunch Rooms (1910.141 (g))

(a) General.

(b) Waste disposal containers.

(c) Location.

4.5.2.8 Food Handling (1910.141 (h))

(a) All employee food service facilities and operations shall meet the requirements of "Food Service Sanitation Ordinance and Code," Part V, "Food Service Sanitation Manual", U.S.P.H. Publication No. 934 (1965), or latest revision.

4.5.2.9 Scope (1910.141 (i))

(a) Above sections apply to all permanent places of employment.

4.5.3 TEMPORARY LABOR CAMPS (1910.142)

A temporary labor camp is defined in ANSI 4.4–68 as any shelter or shelters together with the tract of land appertaining thereto, established for the housing accommodation of persons engaged in any occupation or work for which a labor force is maintained in temporary quarters.

4.5.3.1 Site (1910.142 (a))

(a) All sites must be adequately drained.

(b) All sites must be adequate in size to prevent overcrowding of necessary structures.

(c) The grounds and open areas surrounding the shelters shall be maintained in a clean and sanitary condition free from rubbish, debris, waste paper, garbage and other refuse.

(d) Whenever camp is closed temporarily or permanently, grounds and buildings must be left in a clean and sanitary condition.

4.5.3.2 Shelter (1910.142 (b))

(a) Every shelter in the camp shall be constructed in a manner which will provide protection against the elements.

(b) Each room used for sleeping purposes shall contain at least 50 sq ft of floor space for each occupant. At least a 7-ft ceiling shall be provided.

(c) Beds shall be spaced at least 36 inches both laterally and end to end. If double-deck bunks are used they shall be spaced not less than 48 inches both laterally and end to end. Triple deck bunks are prohibited.

(d) Floors of each shelter shall be constructed of wood, asphalt or concrete. All wood floors shall be elevated not less than 1 foot above the ground.

(e) All living quarters shall be provided with windows the total of which shall not be less than 1/10 of the floor area. At least ½ of each window shall be so constructed that it can be opened for purposes of ventilation.

(f) All exterior openings shall be effectively screened with 16-mesh material and all screen doors equipped with self-closing devices.

(g) All heating, cooking and water-heating equipment shall be installed in accordance with state and local ordinances, codes and regulations governing such installations.

4.5.3.3 Water Supply (1910.142 (c))

(a) An adequate and convenient water supply approved by the appropriate health authority shall be provided in each camp. A water supply shall be deemed adequate if it is capable of delivering 35 gal per person per day at a peak rate of 2½ times the average hourly demand.

(b) The distribution lines shall be capable of supplying water at normal operating pressures to all fixtures for simultaneous operation.

(c) Where water under pressure is available one or more drinking fountains shall be provided for each 100 occupants or fraction thereof.

4.5.3.4 Toilet Facilities (1910.142 (d))

(a) Toilets shall be:

1. Adequate for the camp capacity.
2. Have a window not less than 6 sq ft in area opening direct to the outside or positive ventilation.
3. A toilet room shall be located within 200 ft of the door of any sleeping room.
4. Separate toilet rooms shall be provided for each sex.
5. Lighted either naturally or artificially 24 hours a day.
6. Kept in a sanitary condition. They shall be cleaned at least daily.

4.5.3.5 Sewage Disposal Facilities (1910.142 (e))

(a) In camps where public sewers are available all sewer lines and floor drains from buildings shall be connected thereto.

4.5.3.6 Laundry, Handwashing and Bathing Facilities (1910.142 (f))

(a) Laundry, handwashing and bathing facilities shall be provided in the following ratio:

1. Handwash basin per shelter or per six persons.
2. Shower head for every 10 persons.
3. Laundry tray or tub for every 30 persons.

4.5.3.7 Lighting (1910.142 (g))

(a) Where electric service is available each habital room in a camp shall be provided with at least one ceiling type light fixture and at least one separate floor wall type convenience outlet.

4.5.3.8 Refuse Disposal (1910.142 (h))

(a) Fly-tight, rodent-tight, impervious, cleanable single service containers, approved by the appropriate health authorities shall be provided for the storage of garbage.

(b) Garbage containers shall be kept clean.

(c) Garbage containers shall be emptied when full but not less than twice a week.

(d) Effective measures shall be taken to prevent infestation by and harborage of animal or insect vectors or pests.

4.5.3.9 First Aid (1910.142 (i))

(a) Adequate first-aid facilities approved by a health authority shall be maintained and made available in every labor camp for the emergency treatment of injured persons.

(b) Such facilities shall be in charge of a person trained to administer first aid and shall be readily accessible for use at all times.

4.5.4 NONWATER CARRIAGE DISPOSAL SYSTEMS (1910.143)

4.5.4.1 Acceptable Industrial Disposal Systems

(a) The following waste disposal systems may be used only where not prohibited by codes and regulations of local authorities and where water closets are not feasible due to the location or temporary nature of the operation requiring the facility.

1. Privies (1910.143 (a)).
2. Chemical toilets.
3. Recirculating toilets.
4. Combustion toilets.
5. Portable toilets.

(b) Specifications for each of the above systems are thoroughly covered in Part 1910.143, Subpart J of the Occupational Safety and Health Standards.

Report on Assignment 6

Corrosion Control

H. E. Graham *(chairman, subcommittee)*, H. W. Azer, C. E. DeGeer, D. E. Drake, A. E. Dulik, M. F. Obrecht.

Your committee submits for adoption and publication in the Manual the following new section for Part 6 of Chapter 13.

6.5 CORROSION CONTROL IN ENGINE COOLING SYSTEMS

While there are several types of metal attack that may be encountered in a typical diesel engine cooling system, the scope of this report is concerned with corrosion due to water conditions and its prevention by the proper use and control of inhibitors.

6.5.1 Quality of Water

The water used for fill or makeup to diesel cooling systems should be free from materials that could deposit mud, sludge, scale, or cause corrosion in the cooling system.

6.5.1.1 It is desirable that the total hardness does not exceed 35 ppm as $CaCO_3$; however, water containing hardness up to 170 ppm may be used satisfactorily with appropriate treatment.

6.5.1.2 Distilled, de-ionized, zeolite softened water, or condensate are, with proper inhibitors, recommended for fill or makeup purposes.

6.5.1.3 Natural waters exceeding 170 ppm total hardness should be treated externally to reduce the hardness to 35 ppm or less.

The most common methods used to reduce the hardness are zeolite softening or deionization.

6.5.2 Chemical Concepts

Chemical treatment in diesel engine cooling systems is recommended to prevent and/or control the formation of scale and damage due to corrosion. Inhibitors are available which protect the metallic components of the cooling system from corrosion without adverse effect on non-metallic components and without affecting the heat transfer properties of the metal. Some inhibitors also contain scale suppressants to minimize deposits which may result from use of waters containing hardness.

The two types of inhibitors most commonly used are the chromate type and the borate–nitrite type; however, due to waste-disposal restrictions with these inhibitors, new types are being developed by the water treating companies serving railroads. These systems will provide adequate protection of the cooling system provided proper concentration of the inhibitor is maintained at all times and the cooling system is properly maintained.

6.5.2.1 The chromate inhibitor is generally acknowledged to be the most effective and the most economical, due to lower dosage requirements. This inhibitor has a distinct yellow color that also aids in the detection of water leaks. The minimum treatment level to be maintained in the cooling system is approximately 2100 ppm as sodium chromate with higher levels for certain types of engines, particularly those prone to cavitation-type attack.

A disadvantage of chromate is that it presents waste-disposal problems. Practically all states now have a maximum limit on hexavalent chrome of 0.05 ppm expressed as Cr in wastewater discharged into streams, and there are also restrictions on discharging chromate into a municipal sewer system. While chemicals are available to convert hexavalent chromium into trivalent form which can be precipitated out of the wastewater, this treatment of the waste is complicated and somewhat expensive. Reclamation systems have proven economical in reclaiming chromate-treated cooling water for re-use.

Exposure to chromates may cause dermatitis with some individuals and suitable precautions should be taken to protect employees against chromate dust and chromate solutions.

The chromate-type treatment is not compatible with antifreeze solutions.

6.5.2.2 The borate–nitrite inhibitor requires a higher use concentration to be effective and generally tighter control is required to maintain satisfactory results. The normal recommended dosage is approximately 5600 ppm for the drv product, and 2.0 fluid ounces per gallon for the liquid borate–nitrite inhibitors. The borate–nitrite inhibitors are compatible with antifreeze solutions and they present minimum dermatitis hazards. The disposal of the borate–nitrite compounds is generally less restrictive than the chromate. In some areas, the boron concentration is limited to a maximum of 1 ppm when discharged into streams or municipal sewers.

6.5.2.3 Non-chromate, non-borate corrosion inhibitors have been developed for use where chromate or boron-based products cannot be tolerated due to pollution or disposal restrictions or because of dermatitis considerations. These inhibitors include the all-organic type and those containing sodium nitrite as its principal ingredient. The recommended dosages for these inhibitors are 0.6 fluid ounce per gallon of cooling system capacity for the all-organic type and 1000–2000 ppm of sodium nitrite for the nitrite type inhibitor. These types of treatment are compatible with antifreeze solutions.

6.5.3 Testing

There are a variety of test methods available for determining the concentration of the inhibitor in the cooling system. These tests range from conductivity measurements to simple chemical tests. Most chemical companies that supply the inhibitors can furnish test kits, with detailed instructions, for use in any shop or enginehouse.

6.5.4 Summary

Measures to consider in protecting the cooling systems of diesel locomotives from corrosion are:

(a) Good quality of water supply.

(b) Use of a properly compounded chemical inhibitor which is designed to prevent scale formation and inhibit the mechanism of corrosion found in diesel cooling system environments.

(c) Adequate testing with checking done often enough to insure that the recommended concentration of inhibitor is maintained in the cooling system at all times.

(d) Good maintenance of the cooling system.

(e) Proper facilities to insure that all fill and makeup water for cooling systems is adequately protected with recommended inhibitors.

(f) Proper precautions when treatments are used which may cause dermatitis.
(g) Proper precautions to meet state or local regulations when draining cooling systems.
(h) Consideration should be given to the installation of reclamation systems to reclaim the chromate treated cooling water for re-use.

Manual Recommendations

Committee 7—Timber Structures

W. S. Stokley, *Chairman*

Your committee submits for adoption the following recommendation with respect to Chapter 7 of the Manual:

SPECIFICATIONS FOR DESIGN OF WOOD BRIDGES AND TRESTLES FOR RAILWAY LOADING

On page 7–2–1, add the following new Art. 2 to Sec. A:

2. Design of Public Works Projects

(a) The design, plans, special provisions and specifications for railroad bridges to be built as a public works project and paid for with public funds administered by a public agency shall be prepared by the engineering staff of the railroad involved or by a consulting engineer whose selection has been mutually approved by the railroad and the public agency. The intention of this requirement is that if a consultant is selected, it shall be one who is familiar with the design of railroad bridges, and particularly with the special requirements and operating conditions of the railroad concerned so that the time involvement of the railroad's engineering staff will be minimized.

(b) If a consulting engineer is engaged, the contract for his services may be administered by the public agency or by the railroad if it so desires. In either case, the technical aspects of the work of the consulting engineer shall be under the direction of the railroad and the final plans and specifications must meet with the approval of the railroad.

Manual Recommendations

Committee 28—Clearances

R. T. Pritchett *(chairman, Subcommittee on Revision of Manual)* E. E. Kessler *(chairman, Subcommittee on Compilation of the Railroad Clearance Requirements of the Various States)*, L. R. Beattie, J. E. Beran, E. Berendt, E. S. Birkenwald, G. Buck, R. P. Christman, J. E. Cosky, J. A. Crawford, S. M. Dahl, M. E. Dust, C. W. Farrell, G. E. Henry, J. C. Hobbs, G. P. Huhlein, L. R. Hurd, C. F. Intlekofer, J. L. Kampwirth, R. G. Klouda, A. J. Kozak, E. C. Lawson, D. W. LaPorte, G. W. Martyn, W. E. Morgus, A. E. Moonney, J. R. Moore, F. B. Persels, C. E. Peterson, M. L. Power, P. T. Sarris, L. Schmitz, E C. Smith, R. R. Snyder, C. E. Stephenson, J. E. Teall, W. S. Tustin, W. Trezise, M. Van Kuiken, M. E. Vosseller.

Your committee, following letter ballot approval of its voting members, recommends reorganizing Chapter 28 of the Manual into a decimal format as outlined in the following Table of Contents, with no changes in existing text or diagrams, except: the deletion of "Suggested Measuring Devices for Checking Oversize High-Wide Loads," pages 28–M–7 and 28–M–8; and the revision and extension of "Tables for Computing Curve Offsets on Overhanging Loads," pages 28–M–9 through 28–M–11. The committee also recommends for inclusion in reorganized Chapter 28, for convenient reference, Plates D, E and F of the Mechanical Division, Association of American Railroads; and the adoption as Manual material of a tabulation showing the "Legal Clearances Requirements" of the various states.

The revised and extended tables for computing curve offsets on overhanging loads; Plates D, E, and F of the Mechanical Division, AAR; and the tabulation of the state legal clearance requirements are presented on following pages.

CHAPTER 28

CLEARANCES

TABLE OF CONTENTS

Page

Part I—Clearance Diagrams—Fixed Obstructions

1.1 Special Notes 28–1–1
1.2 Railway Bridges 28–1–2
1.3 Single-Track Tunnel 28–1–3
1.4 Double-Track Tunnel 28–1–4
1.5 Structures (Other Than Platforms) Adjacent to Industrial Side Tracks 28–1–5
1.6 Building Doors 28–1–6
1.7 Platforms 28–1–7
1.8 Third-Rail Territory 28–1–8

Part 2—Equipment Diagrams

2.1 Equipment Diagram for Unrestricted Interchange Service—Plate B 28–2–1
2.2 Maximum Width of Cars with Various Truck Centers—Plate B-1 28–2–2

2.3 Equipment Diagram for Limited Interchange Service—Plate C. . 28–2–3
2.4 Maximum Width of Cars with Various Truck Centers—Plate C-1 28–2–4
2.5 Method of Obtaining Maximum Allowable Width of Car, Other Than at Centerline of Car, for Unrestricted (Plate B-1) and Limited (Plate C-1) Interchange Service—Plate D 28–2–5
2.6 Equipment Diagram for Limited Interchange Service—Plate E . 28–2–6
2.7 Equipment Diagram for Limited Interchange Service—Plate F . 28–2–7
2.8 Outline Diagram for Single Loads, Without End Overhang, on Open Top Cars 28–2–8

Part 3—Miscellaneous

3.1 Clearance Allowances for Horizontal Movements of Passenger Cars Due to Lateral Play, Wear and Spring Deflection 28–3–1
3.2 Suggested Method of Presenting Published Clearances 28–3–7
3.3 Suggested Method of Charting All Obstructions 28–3–10
3.4 Instructions Regarding Information to be Reported for an Excess Dimension Load or Miscellaneous Railroad Equipment Involving Clearances, Weight and High Center of Gravity 28–3–11
3.5 Tables for Computing Curve Offsets on Overhanging Loads .. 28–3–17
3.6 Legal Clearance Requirements by States 28–3–27

TABLE 1
Sheet 1 of 4

28-3-20

TABLE FOR COMPUTING MID-ORDINATES AND CURVE OFFSETS ON LOADS

A R E A COMMITTEE 28 CLEARANCES

NOTE Chord lengths shown in feet, mid-ordinates are in inches

	DEGREE OF CURVE																			
Chord	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
20	.10	21	31	42	52	63	73	84	94	1.05	115	126	136	147	157	168	178	188	199	209
21	12	23	35	46	58	69	81	92	104	1.15	127	139	150	162	173	185	196	208	219	231
22	.13	25	38	51	.63	76	89	101	114	127	139	152	165	177	180	203	215	228	241	253
23	14	28	42	55	69	83	97	111	125	1.38	152	166	180	194	208	222	235	249	263	277
24	.15	.30	45	60	75	.90	1.06	1.21	1.36	1.51	1.66	181	196	211	225	241	256	271	286	302
25	16	33	49	65	82	.98	115	131	147	164	180	196	213	229	245	262	278	295	311	327
26	18	35	53	71	.88	106	1.24	142	159	177	195	212	230	248	265	283	301	319	336	354
27	19	38	57	76	95	115	134	153	172	191	210	229	248	267	285	305	324	344	363	382
28	21	41	62	82	103	123	144	164	185	205	226	246	267	287	308	328	349	369	390	310
29	22	44	66	88	1.10	132	154	176	198	220	242	264	286	308	330	352	374	396	418	440
30	24	47	71	94	118	141	165	188	212	236	259	283	306	3.30	353	377	401	424	448	471
31	25	50	75	101	126	151	176	201	226	252	277	302	327	352	377	403	428	453	478	503
32	27	54	80	107	134	161	188	214	241	268	295	322	348	375	402	429	456	483	509	536
33	.29	57	86	114	143	171	200	228	257	285	314	342	371	398	428	456	485	513	542	570
34	30	61	91	121	151	182	212	242	272	303	333	363	393	424	454	484	514	545	575	605
35	32	64	96	128	160	192	224	257	289	321	353	385	417	449	481	513	545	577	609	641
36	34	68	102	136	170	204	237	271	305	339	373	407	441	475	509	543	577	611	645	679
37	36	72	108	143	179	215	251	287	323	358	394	430	466	502	538	573	609	645	681	717
38	38	76	113	151	189	227	265	302	340	378	416	454	491	529	567	605	643	680	718	756
39	40	80	119	159	199	239	279	319	358	398	438	478	518	557	597	637	677	717	757	796
40	42	84	126	168	209	251	293	335	377	419	461	503	545	586	628	670	712	754	796	838
41	44	88	132	176	220	264	308	352	396	440	484	528	572	616	660	704	748	792	836	880
42	46	92	138	185	231	277	323	369	416	462	508	554	600	646	693	739	785	831	877	924
43	48	97	145	194	242	290	339	387	436	484	532	581	629	678	726	774	823	871	919	968
44	51	101	152	203	253	304	355	405	456	507	557	608	659	710	760	811	862	912	963	1014
45	53	106	159	212	265	318	371	424	477	530	583	636	689	742	795	848	901	954	1007	1060
46	55	111	166	222	277	332	388	443	499	554	609	665	720	775	831	886	942	997	1052	1108
47	58	116	173	231	289	347	405	463	520	578	636	694	752	810	867	925	983	1041	1099	1157
48	60	121	181	241	302	362	422	483	543	603	663	724	784	844	905	965	1025	1086	1146	1206
49	63	126	189	251	314	377	440	503	566	629	691	754	817	880	943	1006	1069	1131	1194	1257
50	65	131	196	262	327	393	458	524	589	654	720	785	851	916	982	1047	1113	1178	1243	1309
51	68	136	204	272	340	409	477	545	613	681	749	817	885	953	1021	1089	1158	1126	1294	1362
52	71	142	212	283	354	425	495	566	637	708	779	849	920	991	1062	1133	1203	1274	1345	1416
53	74	147	221	294	368	441	515	588	662	735	809	882	956	1029	1103	11.77	1250	1324	1397	1471
54	76	153	229	305	382	458	534	611	687	763	840	916	992	1069	1145	1221	1298	1374	1450	1527
55	79	158	238	317	396	475	5.54	636	713	792	871	950	1029	1109	1188	1267	1346	1425	1505	1584
56	82	164	246	328	410	492	575	657	739	821	903	985	1067	1149	1231	1314	1396	1478	1560	1642
57	85	170	255	340	425	510	595	680	765	851	936	1021	1106	1191	1276	1361	1446	1531	1616	1701
58	88	176	264	352	440	528	616	705	793	881	969	1057	1145	12.33	1321	1409	1497	1585	1673	1761
59	.91	182	273	365	456	547	638	729	820	911	1002	1094	1185	1276	1367	1458	1549	1640	1731	1823
60	.94	188	283	377	471	565	660	754	848	942	1037	1131	1225	1319	1414	1508	1602	1696	1791	1885
61	97	195	292	390	487	584	682	779	877	974	1071	1169	1266	1364	1461	1559	1656	1753	1851	1948
62	1.01	201	302	403	503	604	704	805	906	1006	11.07	1208	1308	1409	1509	1610	1711	1811	1912	2013
63	104	208	312	416	520	623	727	831	935	1039	1143	1247	13.51	1455	1559	1662	1766	1870	1974	2078
64	107	2.14	322	429	536	643	751	858	965	1072	1179	1287	1394	1501	1608	1716	1823	1930	2087	2045
65	111	221	332	442	553	664	774	884	995	1106	1217	13.27	1438	15.48	1659	1770	1880	1991	2101	2212
66	114	2.28	342	456	5.70	684	798	912	1026	1140	1254	1368	1482	1596	1710	1825	1939	2053	2167	2281
67	118	235	353	470	588	705	823	940	1058	1175	1293	1410	15.28	1645	1763	1880	1998	2115	2233	2350
68	121	242	363	484	605	726	847	968	1089	1210	1332	1453	15.74	1695	1816	1937	2058	2179	2300	2421
69	125	249	374	499	623	748	872	997	1122	1246	1371	1496	1620	1745	1870	1994	2119	2243	2368	2493
70	128	257	385	513	641	770	898	1026	1154	1283	1411	1539	16.68	1796	1924	2052	2181	2309	2437	2565
71	132	264	396	528	660	792	924	1056	1188	1320	1452	1584	1716	1847	1979	2111	2243	2375	2507	2639
72	136	271	407	543	679	814	950	1086	1221	1357	1493	1628	1764	1900	2036	2171	2307	2443	2578	2714
73	140	279	419	5.58	698	837	977	1116	1256	1395	15.35	1674	1814	1953	2093	2232	2372	2511	2651	2790
74	143	287	430	573	717	860	1003	1147	1290	1434	15.77	1720	1864	2007	2150	2294	2437	2580	2724	2867
75	147	295	442	589	736	884	1031	1178	1325	14.73	1620	1767	1914	2062	2209	2356	2503	2651	2798	2945
76	151	302	454	605	756	907	1058	1210	1361	1512	16.63	1814	1966	21.17	2268	2419	2570	2722	2873	3024
77	155	310	466	621	776	931	1086	1242	1397	1552	1707	1863	2018	21.73	2328	2483	2639	2794	2949	3104
78	159	319	478	637	796	956	1115	1274	1433	1593	1752	1911	2070	22.30	2389	2548	2708	2867	3026	3185
79	163	327	490	654	817	980	1144	1307	1470	1634	1797	1961	2124	2287	2451	2614	27.77	2941	3104	3268
80	168	335	503	670	838	1005	1173	1340	1508	1675	1843	2010	21.78	2346	2513	2681	28.48	3016	3183	3435
81	1.72	344	515	687	859	1031	1202	1374	1546	1718	1889	2061	2233	2405	2576	2748	2920	3092	3263	3435
82	1.76	352	528	704	880	1056	1232	1408	1584	1760	1936	2112	2288	2464	2640	2816	2992	3168	3344	3520
83	180	361	541	721	9.02	1082	1262	1443	1623	1803	19.84	2164	23.44	2525	2705	2885	3066	3246	3426	3607
84	1.85	369	554	739	924	11.08	1293	1478	1662	1847	2032	2217	2401	2586	2770	2955	31.40	3325	3510	3694
85	189	378	567	757	946	11.35	13.24	1513	1702	1891	20.80	22.70	2459	2648	2837	3026	3215	3404	3594	3783
86	194	387	581	774	968	1162	13.55	1549	1743	1936	2130	23.23	25.17	2711	2904	3098	3291	3485	3679	3872
87	198	396	594	792	991	11.89	1387	15.85	1783	1981	2180	2378	25.76	2774	2972	31.70	33.68	3567	3765	3963
88	2.03	405	608	811	1014	12.16	14.19	1622	1825	2027	2230	2433	26.35	2838	30.41	3244	3446	3649	3842	4054
89	2.07	415	622	829	1037	1244	1451	1659	1866	2074	2281	2488	2696	2903	3110	3318	3525	3732	3940	4147
90	2.12	424	636	848	1060	12.72	1484	16.96	19.08	2120	23.32	2545	2757	2969	31.81	33.93	36.05	3817	4029	4241
91	217	434	650	867	1084	1301	1517	17.34	1951	21.68	23.85	26.01	2818	3035	32.52	3468	36.85	3902	4119	4336
92	222	443	665	886	1108	13.29	15.51	17.73	1994	2216	2437	2659	2880	31.02	3324	3545	3767	3988	4210	4431
93	2.26	453	679	906	1132	13.58	15.85	1811	2038	2264	2490	2717	2943	3170	3396	3623	3849	4075	4302	4528
94	2.31	463	694	9.25	1157	1388	16.19	1850	2082	2313	25.44	2776	30.07	3238	3470	3701	3932	4184	4395	4626
95	2.36	473	7.09	945	1181	1418	1654	1890	2126	2363	25.99	28.35	3071	33.08	3544	3780	4016	4253	4489	4725
96	241	483	724	965	1206	14.48	1689	1930	2171	2413	26.54	28.95	3136	3378	36.19	3860	41.01	4343	4584	48.25
97	246	493	739	985	1232	1478	1724	1970	2217	2463	2709	2956	3202	3448	3695	39.41	4187	4434	4680	4926
98	251	503	754	10.06	1257	15.08	1760	2011	2263	2514	2766	3017	3268	3520	3771	4023	4274	4525	4777	5028
99	257	513	770	1026	1283	1539	1796	2053	2309	2566	28.22	3079	33.35	3592	3849	4105	4362	4618	4875	5131
100	262	524	785	1047	1309	15.71	18.32	2094	2356	2618	2880	31.41	3403	3665	3927	4188	4450	4712	4974	5236
101	267	534	801	1068	1335	1602	1869	2136	2403	2670	2937	32.05	3472	3739	4006	4273	4540	4807	5074	53.41
102	272	545	817	10.89	1362	1634	1906	2179	2451	2724	2996	3268	3541	38.13	4085	4358	4630	4902	5175	5447
103	278	555	833	1111	1389	1666	1944	2222	2500	2777	3055	3333	3610	3888	4166	4444	4721	4999	5277	5554
104	283	566	849	11.33	1416	1699	1982	2265	2548	2831	31.15	3398	3681	3964	4247	4530	4813	5097	5380	5663
105	289	577	866	1154	1443	1732	2020	2309	2598	2886	31.75	3463	3752	4041	4329	4618	4906	5195	5484	5772
106	294	588	882	1177	1471	1765	2059	2353	2647	2941	3235	35.30	3824	4118	4412	4706	5000	5294	5589	5883
107	3.00	599	899	1199	1499	1798	2098	2398	2697	2997	3297	3597	3896	4196	4496	4795	5095	5395	5695	5994
108	305	611	916	1221	1527	18.32	2137	2443	2748	3053	3359	3664	3969	4275	4580	4885	5191	5496	5801	6107
109	311	622	933	1244	1555	1866	2177	2488	2799	3110	34.21	3732	4043	43.54	4665	4976	5287	5598	5909	6220
110	317	634	950	1267	1584	19.01	2217	2534	2851	3168	3484	3801	4118	4435	4751	5068	5385	5702	6018	6335
111	323	645	968	1290	1613	1935	2258	2580	2903	3225	3548	3870	4193	4516	4838	5161	5483	5806	6128	6457
112	328	657	9.85	13.14	1642	1970	2299	2627	2955	3284	3612	3941	4269	4597	4926	52.54	5582	5911	6239	6568
113	334	669	1003	1337	1671	2006	23.40	2647	3008	3343	36.77	4011	4345	4680	50.14	53.48	5683	60.17	6351	6685
114	340	680	1021	13.61	1701	2041	2381	27.22	3062	3402	3742	4083	4423	4763	5103	5443	5784	6124	6464	68.04
115	346	692	1039	1385	1731	2077	2423	2770	3118	3462	3808	4154	4501	48.47	5193	55.39	5885	6232	6578	6924
116	352	705	10.57	1409	1761	21.14	2466	2818	3170	3523	3875	42.27	4579	4932	5284	5636	5988	63.41	6693	7045
117	358	717	1075	1433	1792	2150	25.08	2867	3225	3584	3942	4300	4659	5017	53.75	5734	6092	6450	6809	7167
118	365	729	1094	1458	18.23	2187	2552	2916	3281	3645	40.10	43.74	4739	5103	5468	5832	6197	6561	6926	7290
119	371	741	1112	1483	1854	2224	2595	2966	3336	3707	4078	4448	4819	51.90	5561	59.31	6302	6673	7043	7414
120	377	754	1131	1508	1885	2262	2639	3016	3393	3770	4147	4524	4901	5277	5654	6031	6408	6785	7162	75.39
121	3.83	767	1150	1533	1916	2300	2683	3066	3449	3833	4216	4599	4983	5386	5749	6132	6516	6899	7282	7665
122	390	779	1169	1559	1948	2338	2727	3117	3507	3896	4286	4676	5065	5455	5845	6234	6624	7013	74.03	7793
123	396	792	1188	15.84	1980	2376	2772	3168	3564	3960	43.57	47.53	5149	5545	5941	6337	6733	7129	75.25	79.21
124	403	8.05	1208	1610	2013	2415	2818	3220	3623	4025	4428	4830	5233	5635	6038	6440	6843	7245	7648	8050
125	409	818	1227	1636	2045	2454	2863	3272	3681	4090	4499	49.08	5317	5726	6135	6545	6954	7363	7772	8181
126	416	831	1247	1662	2078	2494	2909	33.25	3740	4156	4572	4987	5403	5818	6234	6650	7065	7481	78.96	8312
127	422	844	1267	1689	2111	25.33	2956	3378	3800	4222	4644	5067	5489	5911	6333	67.56	7178	7600	8022	8445
128	429	858	1287	1716	2145	2573	3002	3431	3860	4289	4718	5147	5576	6005	6434	68.62	7291	7720	8149	8578
129	436	871	13.07	1743	2178	2614	3049	3485	39.21	4356	4792	52.28	5663	6099	6534	6970	7406	7841	8277	8713
130	4.42	885	1327	1770	2212	2654	3097	3539	3982	4424	4866	5309	5751	6194	6836	7079	7521	7963	8406	8848
131	449	898	1348	1797	2246	2695	3145	3594	4043	4492	4942	5391	5884	6289	6739	7188	7637	8086	85.36	8985
132	456	912	1368	1825	22.81	2737	3193	3649	4105	4561	50.17	5474	5930	6386	6842	7298	7754	8210	8666	9123
133	463	926	1389	1852	2315	2778	3241	3705	4168	4631	5094	55.57	6020	6483	6946	7409	7872	8335	8798	9261
134	470	940	1410	1880	2350	2820	3290	3760	4230	4701	5171	56.41	6111	6581	7051	7521	7971	8461	89.31	9401
135	477	954	1431	1908	2385	2863	3340	3817	4294	4771	5248	5725	6202	6679	7156	7634	8111	8588	9065	9542

TABLE 1 (continued)
Sheet 2 of 4

TABLE FOR COMPUTING MID-ORDINATES AND CURVE OFFSETS ON LOADS

28-3-22

AREA COMMITTEE 28 CLEARANCES

NOTE Chord lenghts shown in feet, mid-ordinates are in inches

Chord	DEGREE OF CURVE																			
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
136	484	968	1453	1937	2421	2905	3389	3874	4358	4842	5326	5810	6294	6779	7263	7747	8231	8715	9200	9684
137	491	983	1474	1965	2457	2948	3439	3931	4422	4913	5405	5896	6387	6879	7370	7861	8353	8844	9335	9827
138	499	997	1496	1994	2493	2991	3490	3988	4487	4985	5484	5982	8481	6979	7478	7977	8475	8974	9472	9971
139	506	1012	1517	2023	2529	3035	3540	4046	4552	5058	5564	6069	6575	70.81	7587	8093	8598	9104	9610	10116
140	513	1026	1539	2052	2565	3079	3592	4105	4618	5131	5644	6157	6670	7183	7696	8209	8723	9236	9749	10262
141	520	1041	1561	2082	2602	3123	3643	4164	4684	5204	5725	6245	6766	7286	7807	8327	8848	9368	9888	10409
142	5.28	1056	1584	2111	2639	3167	3695	4223	4751	52.79	5806	63.34	6862	7390	7918	8446	8974	9501	10029	10557
143	535	1071	1606	2141	2677	3212	3747	4283	4818	5353	5888	6424	6959	7494	8030	8565	9100	9636	10171	10706
144	543	1066	1828	2171	2714	3257	3800	4343	4885	5428	5971	6514	7057	7600	8142	8685	9228	9771	10314	10857
145	550	11.01	1651	2202	2752	3302	3853	4403	4954	5504	6054	6605	71.55	7705	8256	8806	9357	9907	10457	11008
146	558	1116	1874	2232	2790	3348	3906	4464	5022	5580	6138	6696	7254	7812	8370	8928	9486	10044	10602	11160
147	566	1131	1697	2263	2828	3394	3960	4525	5091	5657	6222	6788	7354	7920	8485	9051	9617	10182	10748	11314
148	573	1147	1720	2294	2867	3440	4014	4587	5161	5734	6307	6881	7454	8028	8601	9174	9748	10321	10895	11468
149	581	1162	1744	2325	2906	3487	4068	4649	5231	5812	6393	6974	7555	8136	8718	9299	9880	10461	11042	11624
150	589	1178	1767	2356	2945	3534	4123	4712	5301	5890	6479	7068	7657	8246	8835	9424	10013	10602	11191	11780
151	597	1194	1791	2388	2984	3581	4178	4775	5372	5969	6566	7163	7760	8356	8953	9550	10147	10744	11341	11938
152	6.05	1210	1814	2419	3024	3629	4234	4839	5443	6048	6653	7258	7863	8467	90.72	9677	10282	10887	11492	12096
153	613	1226	1838	2451	3064	3677	4290	4902	5515	6128	6741	7354	7966	8579	9192	9805	10418	11030	11643	12256
154	621	1242	1863	2483	3104	3725	4346	4967	5588	6208	6829	7450	8071	8692	9313	9933	10554	11175	11796	12417
155	629	1258	1887	2516	3145	3774	4402	5031	5660	6289	6918	7547	8176	8805	9434	10063	10692	11321	11950	12579
156	637	1274	1911	2548	3185	3822	4459	5097	5734	63.71	7008	7645	8282	8919	9556	10193	10830	11467	12104	12741
157	645	1291	1936	2581	3226	3872	4517	5162	5807	6453	7098	7743	8388	9034	9679	10324	10969	11615	12260	12905
158	854	1307	1961	2614	3268	3921	4575	5228	5882	6535	7189	7842	8496	9149	9803	10456	11110	11763	12417	13070
159	662	1324	1985	2647	3309	3971	4633	5294	5956	6618	7280	7942	8603	9265	9927	10589	11251	11913	12574	13236
160	670	1340	20.10	2681	3351	4021	4691	5361	60.31	6702	7372	8042	8712	9382	10052	10723	11393	12063	12733	13403
161	679	1357	2036	2714	3393	4071	4750	5428	6107	6766	7464	8143	8821	9500	10178	10857	11536	12214	12893	13571
162	687	1374	2061	2748	3435	4122	4809	5496	6183	6870	7557	8244	8931	9618	10305	10992	11679	12366	13053	13740
163	696	1391	2087	2782	3478	4173	4869	5564	6260	6955	7651	8346	9042	9737	10433	11128	11824	12519	13215	13910
164	704	1408	2112	2816	3520	4225	4929	5633	6337	7041	7745	8449	9153	9857	10561	11265	11969	12674	13378	14082
165	713	1425	2138	2851	3563	4276	4989	5702	6414	7127	7840	8552	9265	9978	10690	11403	12116	12829	13541	14254
166	7.21	1443	2164	2885	3607	4328	5050	5771	6492	7214	7935	8656	9378	10099	10820	11542	12263	12985	13706	14427
167	730	1460	2190	2920	3650	4380	5111	5841	6571	7301	8031	8761	9491	10221	10951	11681	12411	13141	13871	14602
168	739	1478	2217	2955	3694	4433	5172	5911	6650	7388	8127	8866	9605	10344	11083	11822	12560	13299	14038	14777
169	748	1495	2243	2991	3738	4486	5234	5981	6729	7477	8224	8972	9720	10467	11215	11963	12710	13458	14206	14953
170	757	1513	2270	3026	3783	4539	5296	6052	6809	7565	8322	9079	9835	10592	11348	12105	12861	13618	14374	15131
171	765	1531	2296	3062	3827	4593	5358	6124	6889	7655	8420	9186	9951	10717	11482	12248	13013	13778	14544	15309
172	774	1549	2323	3098	3872	4647	5421	6196	6970	7745	8519	9293	10068	10842	11617	12391	13166	13940	14715	15489
173	783	1567	2350	31.34	3917	4701	5484	6268	7051	7835	8618	9402	10185	10969	11752	12536	13319	14103	14886	15670
174	793	1585	2378	3170	3963	4755	5548	6341	7133	7926	8718	9511	10303	11096	11888	12681	13474	14266	15059	15851
175	802	1603	2405	3207	4009	4810	5612	6414	7215	8017	8819	9620	10422	11224	12026	12827	13629	14431	15232	16034
176	811	1622	2433	3244	4054	4865	5676	6487	7298	8109	8920	9731	10542	11352	12163	12974	13785	14596	15407	16218
177	820	1640	2460	3281	4101	4921	5741	6561	7381	8201	9021	9842	10662	11482	12302	13122	13942	14762	15582	16403
178	829	1659	2488	3318	4147	4977	5806	6635	7465	8294	9124	9953	10783	11612	12441	13271	14100	14930	15759	16588
179	839	1678	2516	3355	4194	5033	5871	6710	7549	8388	9226	10065	10904	11743	12582	13420	14259	15098	15937	16775
180	848	1696	2545	3393	4241	5089	5937	6785	7634	8482	9330	10178	11026	11874	12723	13571	14419	15267	16115	16963
181	858	1715	2573	3430	4288	5146	6003	6861	7719	8576	9434	10291	11149	12007	12864	13722	14580	15437	16295	17152
182	867	1734	2601	3468	43.36	5203	6070	6937	7804	8671	9538	10405	11273	12140	13007	13874	14741	15608	16475	17342
183	877	1753	2630	3507	4383	5260	6137	7013	7890	8767	9643	10520	11397	12273	13150	14027	14903	15780	16657	17534
184	886	1773	2659	3545	4431	5318	6204	7090	7977	8863	9749	10635	11522	12408	13294	14181	15067	15953	16839	17726
185	896	1792	2688	3584	4480	5376	6272	7168	8063	8959	9858	10751	11647	12543	13439	14335	15231	16127	17023	17919
186	906	1811	2717	3623	4528	5434	6340	7245	8151	9057	9962	10868	11774	12679	13585	14490	15396	16302	17207	18113
187	915	1831	2746	3662	4577	5493	6408	7323	8239	9154	10070	10985	11900	12816	13731	14647	15562	16478	17393	18308
188	925	1850	2776	3701	4626	5551	6477	7402	8327	9252	10178	11103	12028	12953	13879	14804	15729	16654	17579	185.05
189	935	1870	2805	3740	4676	5611	6546	7481	8416	9351	10286	11221	12156	13091	14027	14962	15897	16832	17767	18702
190	945	1890	2835	3780	4725	5670	6615	7560	8505	9450	10395	11340	12285	13230	14175	15120	16065	17010	17955	18901
191	955	1910	2865	3820	4775	5730	6685	7640	8595	9550	10505	11460	12415	13370	14325	15280	16235	17190	18145	19100
192	965	1930	2895	3860	4825	5790	6755	7720	8685	9650	10615	11580	12545	13510	14475	15440	16405	17370	18335	19301
193	975	1950	2925	3900	4876	5851	6826	7801	8776	9751	10726	11701	12676	13651	14627	15602	16577	17552	18527	19502
194	985	1970	2956	3941	4926	5911	6897	7882	8867	9852	10838	11823	12808	13793	14779	15764	16749	17734	18719	19705
195	995	1991	2986	3982	4977	5973	6968	7963	8959	9954	10950	11945	12940	13936	14931	15927	16922	17918	18913	19908
196	1006	2011	3017	4023	5028	6034	7040	8045	9051	10057	11062	12068	13074	14079	15085	16090	17096	18102	19107	20113
197	1016	2032	3048	4064	5080	6096	7112	8128	9143	10159	11175	12191	13207	14223	15239	16255	17271	18287	19303	20319
198	1026	2053	3079	4105	5131	6158	7184	8210	9237	10263	11289	12315	13342	14368	15394	16421	17447	18473	19499	20526
199	1037	2073	3110	4147	5183	6220	7257	8293	9330	10367	11403	12440	13477	14513	15550	16587	17623	18660	19697	20734
200	1047	2094	3141	4188	5236	6283	7330	8377	9424	10471	11518	12565	13613	14660	15707	16754	17801	18848	19895	20942
201	1058	2115	3173	4230	5288	6346	7403	8461	9519	10576	11634	12691	13749	14807	15864	16922	17980	19037	20095	21152
202	1068	2136	3205	4273	5341	6409	7477	8545	9614	10682	11750	12818	13886	14954	16023	17091	18159	19227	20295	21363
203	1079	2158	3236	4315	5394	6473	7551	8630	9709	10788	11866	12945	14024	15103	16182	17260	18339	19418	20497	21575
204	1089	2179	3268	4358	5447	6537	7626	8715	9805	10894	11984	13073	14173	15252	16343	17431	18520	19610	20699	21788
205	1100	2200	3300	4401	5501	6601	7701	8801	9901	11001	12101	13202	14302	15402	16502	17602	18702	19802	20902	22003
206	1111	2222	3333	4444	5554	6665	7776	8887	9998	11109	12220	13331	14442	15552	16663	17774	18885	19996	21107	22218
207	1122	2243	3365	4487	5609	6730	7852	8974	10095	11217	12339	13460	14582	15704	16826	17947	19069	20191	21312	22434
208	1133	2265	3398	4530	5663	6795	7928	9061	10193	11326	12458	13591	14723	15856	16988	18121	19254	20386	21519	22651
209	1143	2287	3430	4574	5717	6861	8004	9148	10291	11435	12578	13722	14865	16009	17152	18296	19439	20583	21726	22870
210	1154	2309	3463	4618	5772	6927	8081	9236	10390	11545	12699	13853	15008	16162	17317	18471	19626	20780	21935	23089
211	1165	2331	3496	4662	5827	6993	8158	9324	10489	11655	12820	13986	15151	16317	17482	18648	19813	20978	22144	23309
212	1177	2353	3530	4706	5883	7059	8236	9412	10589	11765	12942	14119	15295	16472	17648	18825	20001	21178	22354	23531
213	1188	2375	3563	4751	5938	7126	8314	9501	10689	11877	13064	14252	15440	16627	17815	19003	20190	21378	25566	23753
214	1199	2398	3597	4795	5994	7193	8392	9591	10790	11988	13187	14386	15585	16784	17983	19182	20383	21579	22778	23977
215	1210	2420	3630	4840	6050	7260	8471	9681	10891	12101	13311	14521	15731	16941	18151	19361	20571	21781	22991	24202
216	1221	2443	3664	4885	6107	7328	8550	9771	10992	12214	13435	14656	15878	17099	18320	19542	20763	21984	23206	24427
217	1233	2465	3698	4931	8163	7396	8629	9862	11094	12327	13560	14792	16025	17258	18490	19723	20856	22189	23421	24654
218	1244	2488	3732	4976	6220	7464	8709	9953	11197	12441	13685	14929	16173	17417	18661	19905	21149	22393	23638	24882
219	1256	2511	3767	5022	6278	7533	8789	10044	11300	12555	13811	15066	16322	17577	18833	20088	21344	22599	23855	25110
220	1267	2534	3801	5068	6335	7602	8869	10136	11403	12670	13937	15204	16471	17738	19005	20272	21539	22806	24073	25340
221	1279	2557	3836	5114	6393	7671	8950	10228	11507	12786	14064	15343	16621	17900	19178	20457	21736	23014	24283	25571
222	1290	2580	3870	5161	6451	7741	9031	10321	11611	12902	14192	15482	16772	18062	19352	20643	21733	23223	24513	25803
223	1302	2604	3905	5207	6509	7811	9113	10414	11716	13018	14320	15622	16923	18225	19527	20829	22131	23432	24734	26036
224	1314	2627	3941	5254	6568	7881	9195	10508	11822	13135	14449	15762	17076	18389	19703	21016	22330	23643	24957	26270
225	1325	2651	3976	5301	6626	7952	9277	10602	11927	13253	14578	15903	17228	18554	19879	21204	22529	23955	25180	26505
226	1337	2674	4011	5348	6685	8022	9359	10697	12034	13371	14708	16045	17382	18719	20056	21393	22730	24067	25467	26741
227	1349	2698	4047	5396	6745	8094	9442	10791	12140	13489	14838	16187	17536	18885	20234	21583	22932	24281	25630	26979
228	1361	2722	4083	5443	6804	8165	9526	10887	12248	13608	14969	16330	17691	19052	20413	21773	23134	24495	25856	27217
229	1373	2746	4118	5491	6864	8237	9610	10982	12355	13728	15101	16474	17846	19219	20592	21965	23338	24710	26083	27456
230	1385	2770	4154	5539	6924	8309	9694	11079	12463	13848	15233	16618	18003	19387	20772	22157	23542	24927	26312	27696
231	1397	2794	4191	5588	6984	8381	9778	11175	12572	13979	15366	16763	18159	19556	20953	22350	23747	25144	26541	27938
232	1409	2818	4227	5636	7045	8454	9863	11272	12681	14090	15499	16908	18317	19726	21135	22544	23953	25362	26771	28180
233	1421	2842	4284	5685	7106	8527	9948	11369	12791	14212	15633	17054	18475	19896	21318	22739	24160	25581	27002	28424
234	1433	2867	4300	5734	7167	8600	10034	11467	12901	14334	15767	17201	18634	20068	21501	22934	24368	25801	27235	28668
235	1446	2891	4337	5783	7228	8674	10120	11565	13011	14437	15902	17348	18794	20240	21685	23131	24577	26022	27468	28914
236	1458	2916	4374	5832	7290	8748	10206	11664	13122	14580	16038	17496	18954	20412	21870	23328	24786	26244	27702	29160
237	1470	2941	4411	5882	7352	8822	10292	11763	13234	14704	16174	17645	19115	20585	22056	23526	24997	26467	27937	29408
238	1483	2966	4448	5931	7414	8897	10380	11863	13345	14828	16311	17794	19277	20760	22242	23725	25208	26691	28174	29657
239	1495	2991	4486	5981	7477	8972	10467	11963	13458	14953	16448	17944	19439	20934	22430	23925	25420	26916	28411	29906
240	1508	3016	4524	6031	7539	9047	10555	12063	13571	15079	16586	18094	19602	21110	22618	24126	25634	27141	28649	30157
241	1520	3041	4581	6082	7602	9123	10643	12164	13684	15204	16725	18145	19766	21286	22807	24327	25848	27368	28888	30409
242	1533	3066	4599	6132	7665	9199	10732	12265	13798	15331	16864	18397	19930	21463	22996	24529	26062	27596	29129	30662
243	1546	3092	4637	6183	7729	9275	10820	12366	13912	15458	17004	18549	20095	21641	23187	24733	26278	27824	29370	30916
244	1559	3117	4676	6234	7793	9351	10910	12468	14027	15585	17144	18702	20261	21819	23378	24937	26495	28054	29612	31171
245	1571	3143	4714	6285	7857	9428	10999	12571	14142	15713	17285	18856	20427	21999	23570	25141	26713	28284	29855	31427
246	1584	3168	4753	6337	7921	9505	11089	12674	14258	15842	17426	19010	20594	22179	23763	25347	26931	28515	30100	31684
247	1597	3194	4791	6388	7985	9583	11180	12777	14374	15971	17568	19165	20762	22359	23956	25554	27151	28748	30345	31942
248	1610	3220	4830	6440	8050	9660	11270	12880	14490	16101	17711	19321	20931	22541	24151	25761	27371	28981	30591	32201
249	1623	3246	4869	6492	8115	9738	11361	12984	14608	16231	17854	19477	21100	22723	24346	25969	27592	29215	30838	32461
250	1636	3272	4908	6545	8181	9817	11453	13089	14725	16361	17997	19634	21270	22906	24542	26178	27814	29450	31086	32723
251	1649	3298	4948	6597	8246	9895	11545	13194	14843	16492	18142	19791	21440	23089	24739	26388	28037	29686	31336	32985

TABLE 1 (continued)
Sheet 3 of 4

TABLE FOR COMPUTING MID-ORDINATES AND CURVE OFFSETS ON LOADS

A R E A COMMITTEE 28 CLEARANCES

NOTE Chord lengths shown in feet, mid-ordinates are in inches

Chord	DEGREE OF CURVE																			
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
252	16.62	33.25	49.18	66.50	83.12	99.14	116.37	132.99	149.62	166.24	182.86	199.49	216.11	232.74	249.36	265.99	282.61	299.23	315.86	332.48
253	16.76	33.51	50.27	67.03	83.78	100.54	117.29	134.05	150.81	167.56	184.32	201.08	217.83	234.59	251.34	268.10	284.86	301.61	318.37	335.13
254	16.89	33.78	50.67	67.56	84.44	101.33	118.22	135.11	152.00	168.89	185.78	202.67	219.56	236.45	253.33	270.22	287.11	304.00	320.89	337.78
255	17.02	34.04	51.07	68.09	85.11	102.13	119.16	136.18	153.20	170.22	187.24	204.27	221.29	238.31	255.33	272.36	289.38	306.40	323.42	340.45
256	17.16	34.31	51.47	68.62	85.78	102.94	120.09	137.25	154.40	171.56	188.72	205.87	223.03	240.18	257.34	274.50	291.65	308.81	325.96	343.12
257	17.29	34.58	51.87	69.16	86.45	103.74	121.03	138.32	155.61	172.90	190.19	207.48	224.77	242.06	259.35	276.64	293.94	311.23	328.52	345.81
258	17.43	34.85	52.28	69.70	87.13	104.55	121.98	139.40	156.83	174.25	191.68	209.10	226.53	243.95	261.38	278.80	296.23	313.65	331.08	348.50
259	17.56	35.12	52.68	70.24	87.80	105.36	121.92	140.48	158.04	175.60	193.17	210.73	228.29	245.85	263.41	280.97	298.53	316.09	333.65	351.21
260	17.70	35.39	53.09	70.79	88.48	106.18	123.87	141.57	159.27	176.96	194.66	212.36	230.05	247.75	265.44	283.14	300.84	318.53	336.23	353.93
261	17.83	35.67	53.50	71.33	89.16	107.00	124.83	142.66	160.49	178.33	196.16	213.99	231.83	249.66	267.49	285.32	303.16	320.99	338.82	356.65
262	17.97	35.94	53.91	71.88	89.85	107.82	125.79	143.76	161.73	179.70	197.67	215.64	233.61	251.57	269.54	287.51	305.48	323.45	341.42	359.39
263	18.11	36.21	54.32	72.43	90.54	108.64	126.75	144.86	162.96	181.07	199.18	217.28	235.39	253.50	271.61	289.71	307.82	325.93	344.03	362.14
264	18.25	36.49	54.74	72.98	91.23	109.47	127.72	145.96	164.21	182.45	200.70	218.94	237.19	255.43	273.68	291.92	310.17	328.41	346.66	364.90
265	18.38	36.77	55.15	73.53	91.92	110.30	128.68	147.07	165.45	183.84	202.22	220.60	238.99	257.37	275.75	294.14	312.52	330.90	349.29	367.67
266	18.52	37.04	55.57	74.09	92.61	111.13	129.66	148.18	166.70	185.22	203.75	222.27	240.79	259.31	277.84	296.36	314.88	333.40	351.93	370.45
267	18.66	37.32	55.99	74.65	93.31	111.97	130.63	149.30	167.96	186.62	205.28	223.94	242.61	261.27	279.93	298.59	317.25	335.92	354.58	373.24
268	18.80	37.60	56.41	75.21	94.01	112.81	131.61	150.42	169.22	188.02	206.82	225.63	244.43	263.23	282.03	300.83	319.64	338.44	357.24	376.04
269	18.94	37.89	56.83	75.77	94.71	113.66	132.60	151.54	170.48	189.43	208.37	227.31	246.25	265.20	284.14	303.08	322.03	340.97	359.91	378.85
270	19.08	38.17	57.25	76.34	95.42	114.50	133.59	152.67	171.75	190.84	209.92	229.01	248.09	267.17	286.26	305.34	324.42	343.51	362.59	381.68
271	19.23	38.45	57.68	76.90	96.13	115.35	134.58	153.80	173.03	192.25	211.48	230.70	249.93	269.16	288.38	307.61	326.83	346.06	365.28	384.51
272	19.37	38.74	58.10	77.47	96.84	116.21	135.57	154.94	174.31	193.68	213.04	232.41	251.78	271.15	290.51	309.88	329.25	348.62	368.98	387.35
273	19.51	39.02	58.53	78.04	97.55	117.08	136.57	156.08	175.59	195.10	214.61	234.12	253.63	273.14	292.65	312.16	331.67	351.18	370.69	390.20
274	19.65	39.31	58.96	78.61	98.27	117.92	137.57	157.23	176.88	196.53	216.19	235.84	255.49	275.15	294.80	314.45	334.11	353.76	373.41	393.07
275	19.80	39.59	59.39	79.19	98.99	118.78	138.58	158.38	178.17	197.97	217.77	237.57	257.36	277.16	296.96	316.75	336.55	356.35	376.14	395.94
276	19.94	39.88	59.82	79.77	99.71	119.65	139.59	159.53	179.47	199.41	219.35	239.30	259.24	279.18	299.12	319.06	339.00	358.94	378.89	398.83
277	20.09	40.17	60.26	80.34	100.43	120.52	140.60	160.69	180.78	200.86	220.95	241.03	261.12	281.21	301.29	321.38	341.46	361.55	381.64	401.72
278	20.23	40.46	60.69	80.93	101.16	121.39	141.62	161.85	182.08	202.31	222.55	242.78	263.01	283.24	303.47	323.70	343.93	364.17	384.40	404.63
279	20.38	40.75	61.13	81.51	101.59	122.26	147.64	163.02	183.39	203.77	224.15	244.53	264.90	285.28	305.66	326.04	346.41	366.79	387.17	407.54
280	20.52	41.05	61.57	82.09	102.62	123.14	143.66	164.19	184.71	205.24	225.76	246.28	266.81	287.33	307.85	328.38	348.90	369.42	389.95	410.47
281	20.67	41.34	62.01	82.68	103.35	124.02	144.69	165.36	186.03	206.70	227.37	248.04	268.72	289.39	310.06	330.73	351.40	372.07	392.74	413.41
282	20.82	41.64	62.45	83.27	104.09	124.91	145.72	166.54	187.36	208.18	229.00	249.81	270.63	291.45	312.27	333.08	353.90	374.72	395.54	416.36
283	20.97	41.93	62.90	83.86	104.83	125.79	146.76	167.73	188.69	209.66	230.62	251.59	272.55	293.52	314.49	335.45	356.42	377.38	398.35	419.31
284	21.11	42.23	63.34	84.46	105.57	126.68	147.80	168.91	190.03	211.14	232.26	253.37	274.48	295.60	316.71	337.83	358.94	380.05	401.17	422.28
285	21.26	42.53	63.79	85.05	106.32	127.58	148.84	170.10	191.37	212.63	233.89	255.16	276.42	297.68	318.95	340.21	361.47	382.74	404.00	425.26
286	21.41	42.83	64.24	85.65	107.06	128.48	149.89	171.30	192.71	214.13	235.54	256.95	278.36	299.78	321.19	342.60	364.01	385.43	406.84	428.25
287	21.56	43.13	64.69	86.25	107.81	129.38	150.94	172.50	194.06	215.63	237.19	258.75	280.31	301.88	323.44	345.00	366.56	388.13	409.69	431.25
288	21.71	43.43	65.14	86.85	108.57	130.28	151.99	173.70	195.42	217.13	238.84	260.56	282.27	303.98	325.70	347.41	369.12	390.84	412.55	434.26
289	21.86	43.73	65.59	87.46	109.32	131.18	153.05	174.91	196.78	218.64	240.51	262.37	284.23	306.10	327.96	349.83	371.69	393.55	415.42	437.28
290	22.02	44.03	66.05	88.06	110.08	132.09	154.11	176.13	198.14	220.16	242.17	264.19	286.20	308.22	330.24	352.25	374.27	396.28	418.30	440.31
291	22.17	44.34	66.50	88.67	110.84	133.01	155.17	177.34	199.51	221.68	243.85	266.01	288.18	310.35	332.52	354.68	376.85	399.02	421.19	443.36
292	22.32	44.64	66.96	89.28	111.60	133.92	156.24	178.56	200.88	223.20	245.52	267.84	290.17	312.49	334.81	357.13	379.45	401.77	424.09	446.41
293	22.47	44.95	67.42	89.89	112.37	134.84	157.31	179.79	202.26	224.74	247.21	269.68	292.16	314.63	337.10	359.58	382.05	404.52	427.00	449.47
294	22.63	45.25	67.88	90.51	113.14	135.76	158.39	181.02	203.64	226.27	248.90	271.53	294.15	316.78	339.41	362.04	384.66	407.29	429.92	452.54
295	22.78	45.56	68.34	91.13	113.91	136.69	159.47	182.25	205.03	227.81	250.60	273.38	296.16	318.94	341.72	364.50	387.28	410.07	432.85	455.63
296	22.94	45.87	68.81	91.74	114.68	137.62	160.55	183.49	206.42	229.36	252.30	275.23	298.17	321.11	344.04	366.98	389.91	412.85	435.79	458.72
297	23.09	46.18	69.27	92.37	115.46	138.55	161.64	184.73	207.82	230.91	254.00	277.10	300.19	323.28	346.37	369.46	392.55	415.64	438.74	461.83
298	23.25	46.49	69.74	92.99	116.24	139.48	162.73	185.98	208.22	232.47	255.72	278.97	302.21	325.46	348.71	371.95	395.20	418.45	441.70	464.94
299	23.40	46.81	70.21	93.61	117.02	140.42	163.82	187.23	210.63	234.03	257.44	280.84	304.24	327.65	351.05	374.45	397.86	421.26	444.66	468.07
300	23.56	47.12	70.68	94.24	117.80	141.36	164.92	188.48	212.04	235.60	259.16	282.72	306.28	329.84	353.40	376.96	400.52	424.08	447.64	471.20

EXAMPLES FOR COMPUTING MID-ORDINATES AND CURVE OFFSETS ON LOADS

GENERAL NOTE

Offsets as shown are those due to curvature only. Where required, lean of load due to superelevation of rails should be calculated separately.

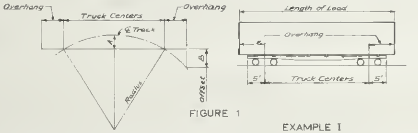


FIGURE 1

EXAMPLE I

Load 70 ft. long on 50 ft car (40 ft truck centers) having equal end overhangs 15 ft long.
To illustrate: From Table 1, the value of mid-ordinate of a 40 ft chord (truck centers of load car) for a 7° curve is 2.93" and the value of mid-ordinate of a 70 ft chord (length of load) on a 7° curve is 8.98". The value of offset B is equal to the difference of 8.98" and 2.93" or 6.05" (6 1/16").
The offset B can be determined for any given distance from truck center on the overhang. For example the offset B at distance of 10 ft. from truck center is calculated as follows: Truck centers of 40 ft plus 2 X 10 ft results in a 60 ft chord which has a mid-ordinate of 6.60" on a 7° curve. Offset B is equal to the difference of (mid-ordinate A) 2.93" and 6.60" or 3.67" (3 11/16").

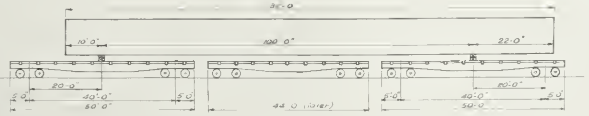
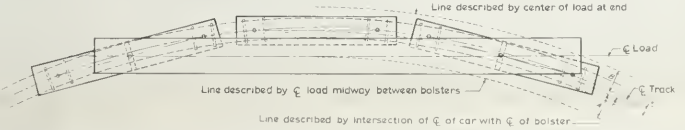


FIGURE 2



Line described by center of load at end
℄ Load
B
℄ Track
Line described by ℄ load midway between bolsters
Line described by intersection of ℄ of car with ℄ of bolster

EXAMPLE II

To illustrate, the value of the mid-ordinate of the 100 ft chord (distance between pivoted bolsters) on a 7° curve is 18.32". The value of the mid-ordinates with the pivoted bolsters located mid-point of 40 ft truck centers is 2.93", therefore, total value of mid-ordinate of the load is 18.32" plus 2.93" or 21.25". The value of a 144 ft chord (100 ft plus 22 ft X 2 = 144 ft or effective length of load) on a 7° curve is 38.00". The difference of the total mid-ordinate of 21.25" and 38.00" is 16.75" or 1 ft 4 3/4 in which is the offset B at the end of a 22 ft overhang. Similarly, the offset at the end of the 10 ft overhang is 5.14" or 5 1/4".

NOTE: If pivoted bolsters are not located at mid-point of truck centers, say 10 ft from nearest truck center, this ordinate value "t" can be obtained directly from Table 2 and is shown as .31" when multiplied by 7 for 7° curve, value becomes 2.17" or 2 3/16".

TABLE 2 - ORDINATES BETWEEN ℄ TRACK AND ℄ CAR AT ℄ BOLSTER ON 1° CURVE

VALUES OF "t" IN INCHES

"D" DISTANCE FROM CENTER OF NEAREST TRUCK	"C" DISTANCE CENTER TO CENTER OF TRUCKS																																			
	20'	22'	24'	26'	28'	30'	32'	34'	36'	38'	40'	41'	42'	43'	44'	45'	46'	47'	48'	49'	50'	51'	52'	53'	54'	55'	56'	57'	58'	59'	60'	61'	62'	63'	64'	65'
1'	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
2'	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13
3'	0.05	0.06	0.07	0.07	0.08	0.08	0.09	0.10	0.10	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19	0.19
4'	0.07	0.08	0.08	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.20	0.20	0.21	0.21	0.21	0.22	0.22	0.23	0.23	0.23	0.24	0.24	0.25	0.25	0.26
5'	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.20	0.21	0.21	0.21	0.22	0.23	0.23	0.24	0.24	0.25	0.25	0.25	0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.30	0.30	0.31	0.31
6'	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.18	0.19	0.20	0.21	0.22	0.23	0.23	0.24	0.25	0.25	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.30	0.31	0.31	0.32	0.33	0.33	0.34	0.35	0.35	0.36	0.36	0.37
7'	0.10	0.11	0.12	0.14	0.15	0.17	0.18	0.20	0.21	0.23	0.24	0.25	0.26	0.26	0.27	0.28	0.29	0.29	0.30	0.31	0.32	0.32	0.33	0.34	0.34	0.35	0.36	0.37	0.37	0.38	0.39	0.40	0.40	0.41	0.42	0.43
8'	0.10	0.12	0.13	0.15	0.17	0.18	0.20	0.22	0.23	0.25	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.34	0.35	0.36	0.37	0.38	0.39	0.39	0.40	0.41	0.42	0.43	0.43	0.44	0.45	0.46	0.47	0.48
9'	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.25	0.27	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53
10'	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.25	0.27	0.29	0.31	0.32	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.56	0.56	0.58
11'		0.13	0.15	0.17	0.20	0.22	0.24	0.27	0.29	0.31	0.33	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.43	0.44	0.45	0.46	0.47	0.48	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.58	0.59	0.60	0.61	0.62
12'			0.15	0.18	0.20	0.23	0.25	0.28	0.30	0.33	0.35	0.36	0.38	0.39	0.40	0.41	0.43	0.44	0.45	0.47	0.48	0.49	0.50	0.50	0.53	0.54	0.55	0.57	0.58	0.59	0.60	0.62	0.63	0.64	0.65	0.67
13'				0.18	0.20	0.23	0.26	0.29	0.31	0.34	0.37	0.38	0.40	0.41	0.42	0.44	0.45	0.46	0.48	0.49	0.50	0.52	0.53	0.54	0.56	0.57	0.59	0.60	0.61	0.63	0.64	0.65	0.67	0.68	0.69	0.71
14'					0.21	0.23	0.26	0.29	0.32	0.35	0.38	0.40	0.41	0.43	0.44	0.45	0.47	0.48	0.50	0.51	0.53	0.54	0.56	0.57	0.59	0.60	0.62	0.63	0.65	0.66	0.67	0.69	0.70	0.72	0.73	0.75
15'						0.24	0.27	0.30	0.33	0.36	0.39	0.41	0.42	0.44	0.46	0.47	0.49	0.50	0.52	0.53	0.55	0.57	0.58	0.60	0.61	0.63	0.64	0.66	0.68	0.69	0.71	0.72	0.74	0.75	0.77	0.79
16'							0.27	0.30	0.34	0.37	0.40	0.42	0.44	0.45	0.47	0.49	0.50	0.52	0.54	0.55	0.57	0.59	0.60	0.62	0.64	0.65	0.67	0.69	0.70	0.72	0.74	0.75	0.77	0.79	0.80	0.82
17'								0.30	0.34	0.37	0.41	0.43	0.45	0.46	0.48	0.50	0.52	0.53	0.55	0.57	0.59	0.61	0.62	0.64	0.66	0.68	0.69	0.71	0.73	0.75	0.77	0.78	0.80	0.82	0.84	0.86
18'									0.34	0.38	0.41	0.43	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.72	0.74	0.75	0.77	0.79	0.81	0.83	0.85	0.87	0.89
19'										0.38	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82	0.84	0.86	0.88	0.90	0.92
20'											0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.57	0.59	0.61	0.63	0.65	0.67	0.69	0.71	0.73	0.75	0.78	0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94
21'													0.46	0.48	0.51	0.53	0.55	0.57	0.59	0.62	0.64	0.66	0.68	0.70	0.73	0.75	0.77	0.79	0.81	0.84	0.86	0.88	0.90	0.92	0.95	0.97
22'															0.51	0.53	0.55	0.58	0.60	0.62	0.65	0.67	0.69	0.71	0.74	0.76	0.78	0.81	0.83	0.85	0.88	0.90	0.92	0.95	0.97	0.99
23'																	0.55	0.58	0.60	0.63	0.65	0.67	0.70	0.72	0.75	0.77	0.80	0.82	0.84	0.87	0.89	0.92	0.94	0.96	0.99	1.01
24'																			0.60	0.63	0.65	0.68	0.70	0.73	0.75	0.78	0.80	0.83	0.86	0.88	0.91	0.93	0.96	0.98	1.01	1.03
25'																					0.65	0.68	0.71	0.73	0.76	0.79	0.81	0.84	0.86	0.89	0.92	0.94	0.97	1.00	1.02	1.05
26'																							0.71	0.74	0.76	0.79	0.82	0.84	0.87	0.90	0.93	0.95	0.98	1.01	1.04	1.06
27'																									0.76	0.79	0.82	0.85	0.88	0.91	0.93	0.96	0.99	1.02	1.05	1.06
28'																											0.82	0.85	0.88	0.91	0.94	0.97	1.00	1.03	1.06	1.09
29'																													0.88	0.91	0.94	0.97	1.00	1.03	1.06	1.09
30'																															0.94	0.97	1.01	1.04	1.07	1.10
31'																																	1.01	1.04	1.07	1.10
32'																																			1.07	1.11

GENERAL NOTES

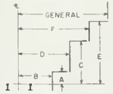
Offsets as shown are those due to curvature only. However, where conditions so require, lean of load due to superelevation of rails should be calculated separately. Sketches of loads shown are for illustration only.

TABLE 2
Sheet 4 of 4

28-3-26

TABLES FOR COMPUTING CURVE OFFSETS ON OVERHANGING LOADS
AREA COMMITTEE 28 CLEARANCES

LEGAL CLEARANCE REQUIREMENTS

	REGULATION REFERENCE		TRACK CENTERS								VERTICAL						HORIZONTAL																					
																							PLATFORMS 						SIGNALS									
																														LOW, BETWEEN TRACKS		SWITCH BOXES, ETC						
			MAIN TRACKS	ANY TWO SUBSIDIARY TRACKS	ADJACENT SUBSIDIARY TRACK TO ANY MAIN TRACK	LADDER TRACK ADJACENT TO ANY PARALLEL TRACK	TWO ADJACENT PARALLEL LADDER TRACKS	LEAD, REPAIR AND CABOOSE TRACKS	TEAM TRACKS IN PAIRS	UNLOADING TRACKS AT PLATFORMS	GENERAL	THRU BRIDGES	HIGHWAY BRIDGES	TUNNELS	BUILDING DOORS	IN BUILDINGS	GENERAL	THRU BRIDGES	HIGHWAY BRIDGES	TUNNELS	BUILDING DOORS	IN BUILDINGS	A	B	C	D	E	F	HIGH	HEIGHT	CLEARANCE	HEIGHT	CLEARANCE	POLES	MAIL CRANES	ICING DOCKS	ORE AND COAL DOCKS	CATTLE CHUTES
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
ALABAMA	NOTE 1																																					
ALASKA	NOTE 1																																					
ARIZONA	G O R-5	1960	14-0	14-0	15-0	20-0	20-0	14-0	11-6	13-0	22-0	22-0	23-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8			4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	E	7-8	8-6	8-6
ARKANSAS	CASE R-1012	1956	14-0	14-0	14-0	17-0	20-0	14-0	13-0	13-0	22-0	22-0	22-0	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[3,5]	7-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
CALIFORNIA	G O 26-D	1964	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0	18-0[4]	8-6	8-0	8-6	8-0	8-6	8-6	0-8	4-8			4-0	7-6[10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	7-8	8-6	8-6
CANADA	G O E-2	1965	13-0	13-6	14-0	15-0	18-0	13-6	12-0	12-0	22-6	22-6	22-6	22-6	22-6	22-6	8-4¼	8-0	8-4¼	8-0	8-4¼	8-4¼	[19]	[19]	[19]	[19]	4-0	[19]	8-4¼		8-4¼			8-4¼	7-1¾[11]	8-4¼	8-4¼	8-4¼
COLORADO	DEC 38476	1961	14-0	14-0	15-0	17-0	20-0	14-0	13-0	15-0	22-6	22-0	22-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0	8-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-6	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
CONNECTICUT	DOCK 8995	1956	13-0	13-0	15-0	18-0	19-0	14-0	13-0	13-0	18-0	18-0[13]	18-0[13]	18-0[13]	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-2			4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-6	8-0	8-6
DELAWARE	ORDER 214	1955	14-0	13-6	15-0	18-0	19-0	13-6	13-0	13-0	22-0	22-0	22-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	7-8	E	8-6
DIST OF COLUMBIA	ORDER	1954	14-0	14-0	15-0	18-0	19-0	14-0	13-0	13-0	22-0	22-0	22-0	22-0	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0	8-0	0-8	4-8	4-0	5-7[7]			8-6	3-0	6-0	0-4	3-0	8-6	8-6	8-6	8-6	8-6
FLORIDA	ORDER 1871	1953	13-6	13-6	13-6	19-0	19-0	13-6	13-0	13-0	22-0	22-0	22-0	22-0[2]	17-0	17-0	8-0	8-0[2]	8-0	8-0[2]	8-0	8-0	0-8	4-8	CFH	5-9			8-0	3-0	6-0	0-4	3-0	10-0	6-5[11]	7-8	8-0	8-0
GEORGIA	NOTE 1																																					
IDAHO	G O 99	1955	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6[3]	0-8	4-8	4-0	7-3	4-0	8-6[10]	8-0	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
ILLINOIS	G O 22	1969	13-6[15]	13-6[15]	15-0	17-0[16]	19-0[17]		13-6	13-6	21-6	21-3	21-6	21-6[2]	H		8-0	8-0	8-0	8-0[2]	7-0[3]	8-0	0-4	4-6	0-8	5-1[9]	CFH	6-2	8-6	2-8				9-0	8-0	8-0	8-0	8-0
INDIANA	STATUTES	1951									22-0	22-0[2]	22-0	22-0	22-0	22-0	8-0	8-0[2]	8-0	8-0[2]	8-0	8-0							8-0					8-0	8-0	8-0	8-0	8-0
IOWA	DOCK K-1281	1936	14-0	13-6[15]	15-0	17-0[16]	19-0[17]		13-6	13-6	22-0	22-0	22-0	22-0[2]	H		8-0	8-0	8-0	8-0[2]	7-0[3]	7-0	0-4	4-6	0-8	5-1[9]	CFH	5-8	8-0	2-8				8-0	6-3[11]	8-0	7-0	8-0
KANSAS	DOCK 58144-R	1958	14-0	14-0	14-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	22-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[5]	7-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
KENTUCKY	STATUTES	1942											22-0																									
LOUISIANA	NOTE 1																																					
MAINE	G O 2	1956									22-0	22-0	22-0	22-0[2]	17-0[3]	17-0	8-0	8-0	8-0	8-0[2]	7-0[3]	8-0	0-12	5-4	4-0	5-9[7]		[10]	8-0	3-2	5-5	0-4	3-0	8-0	6-1[11]	6-0	6-0	8-0
MARYLAND	ORDER 50138	1953	14-0	13-6	15-0	18-0	19-0	13-6	13-0	13-0	22-0	22-0	22-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	7-8	E	8-6
MASSACHUSETTS	STATUTES	1970	13-0	13-0	13-0	17-0	17-0	17-0	13-0	13-0	22-6	22-6	22-6	22-6	22-6	22-6	8-6	8-6[2]	8-6	8-6[2]	8-6					5-9[7]			8-6	3-0	6-6			8-6	8-6	8-6	8-6	8-6
MICHIGAN	STATUTES	1957	14-0	14-0	14-0	14-0	14-0	14-0	14-0	14-0	22-6	E	E	22-6[2]	22-6	22-6	8-6	E	E	8-6[2]	8-6	8-6							E	E	E	E	E	8-6	E	E	E	E
MINNESOTA	STATUTES	1943	14-0	14-0	14-0	17-0	19-0	14-0	14-0	14-0	22-0	22-0	22-0	22-0	22-0[3]	22-0	8-6	8-6	8-6	8-6	8-6[3]	8-6							8-6					8-6	8-6	8-6	8-6	8-6
MISSISSIPPI	NOTE 1																																					
MISSOURI	G O 24	1959	14-0	14-0	14-0	17-0	19-0	14-0	14-0	13-6	22-0	22-0	22-0	22-0	22-0	22-0	8-6	8-0	8-6	8-6	8-6[3]	8-6	0-4	4-6	0-8	5-1[9]	CFH	5-9	8-6	4-0	5-0 TO 6-0	0-3	4-2	8-6	6-5[11]	8-6	8-6	8-6
MONTANA	ORDER 2597	1956	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8	4-0	5-9[7]	4-0	8-6[10]	8-0	3-0	6-0	0-4	3-0	8-6	8-6	5-9	8-6	8-6
NEBRASKA	G O 100	1963	14-0	14-0	15-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	23-0	23-0	17-0	18-0[4]	8-6	8-0	8-6	8-0	7-0[3]	7-0[6]	0-8	5-0	4-0	5-9[6]	4-0	8-6	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
NEVADA	CASE 1159	1947	14-0	14-0	15-0	20-0	20-0	20-0	11-6	13-0	22-0	22-0	23-0	22-0	18-0	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8			4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	E	7-8	8-6	8-6
NEW HAMPSHIRE	ORDER 6922	1956	14-0	14-0	15-0[C]	18-0	18-0	14-0	13-0	13-0	21-0	21-0	21-0	21-0	17-0	17-0	8-0[14]	8-0[14]	8-0[14]	8-0[14]	7-0[3]	8-0	0-12	5-4	4-0	5-9[7]		[10]	8-6	3-2	5-5	0-4	3-0	8-6	6-1[11]	6-0	6-0	8-6
NEW JERSEY	NOTE 1																																					
NEW MEXICO	ORDER 2202	1957	14-0	14-0	15-0	17-0	20-0	14-0	13-0		22-6	22-0	22-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[5]	7-0[6]	0-8	4-8	4-0	5-9[7]	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
NEW YORK	STATUTES	1969	13-6	13-6	15-0	18-0	19-0	13-6	13-6	13-6	22-0	22-0	22-0	22-0	18-0	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-0	E	8-0
NORTH CAROLINA	NOTE 1																																					
NORTH DAKOTA	STATUTES	1943	13-0	13-0	13-0	13-0	13-0	13-0	13-0	13-0	21-0[2]	21-0[2]	21-0	21-0[2]	21-0	21-0	8-0[2]	8-0[2]	8-0	8-0[2]	8-0	8-0					4-0	8-0	8-0					8-0	8-0	8-0	8-0	8-0
OHIO	ORDER 26531	1958	14-0	14-0	15-0	15-0	18-0	14-0			21-0	21-0[2]	21-0	21-0	21-0	21-0	8-0	8-0[2]	8-0	8-0[2]	8-0	8-0							8-0					8-0	8-0	8-0	8-0	8-0
OKLAHOMA	ORDER 33347	1956	14-0	14-0	14-0	17-0	20-0	14-0	13-0	13-0	22-0	22-0	22-0	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[5]	7-0[6]	0-8	5-0	4-0	5-9	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
OREGON	ORDER 33700	1955	15-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6	8-6	0-8	4-8			4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	8-6	7-8	8-6	8-6
PENNSYLVANIA	ORDER	1969	13-6	13-6	15-0	18-0	19-0	13-6	13-6		22-0	22-0	22-0	22-0	18-0	18-0	12-0	8-0	12-0	8-0	8-0	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	12-0	3-0	6-0	0-4	3-0	12-0	6-5[11]	8-0	E	8-6
RHODE ISLAND	DOCK 608	1955	13-0	14-0	15-0	18-0	19-0	14-0	13-0	14-0	18-0	18-0	18-0	18-0	18-0	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-2			4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-6	8-0	8-6
SOUTH CAROLINA	NOTE 1																																					
SOUTH DAKOTA	ORDER F-2465	1957									22-6	22-6	22-6[2]	22-6	17-0	22-6	8-6	8-0	8-0[2]	8-6	7-0	8-6	0-8	4-8	CFH	5-9[7]			8-0			0-4	3-0	8-6	8-6	8-6	8-6	8-6
TENNESSEE	STATUTES	1949	14-0	13-0	14-0	18-0	18-0	14-0	13-0	13-0	22-0	22-0	22-0	22-0	17-0	17-0[4]	8-0	8-0	8-0	8-0	8-0	8-0	0-8	4-8	4-0	5-9	4-0	7-6	8-0		6-6	0-4	3-0	8-0	6-5[11]	7-0	8-0	8-0
TEXAS	STATUTES	1948									22-0	22-0	22-0	22-0	22-0	22-0	8-6	7-6	8-6	8-6[2]	8-6[3]	8-6	0-12	4-6					8-6	2-6	5-6	0-6	4-0	8-6	E	7-0	8-6	8-6
UTAH	G O 66	1953	14-0	14-0	15-0	17-0	20-0	14-0	11-6	11-6	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8	1-9	5-8[9]	4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	E	7-8	8-6	8-6
VERMONT	STATUTES	1951										22-0	22-0				8-0	8-0	8-0	8-0	8-0	8-0																
VIRGINIA	NOTE 1																																					
WASHINGTON	G O T-6499	1969	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0	18-0[4]	8-6	8-0	8-6	8-0	8-6	8-6	0-8	4-8	4-0	7-3	4-0	8-6[10]	8-0	3-0	6-0	0-4	3-0	8-6	8-6	7-3[7]	8-6	8-6
WEST VIRGINIA	G O 164	1970	14-0	14-0	15-0	15-0	18-0	14-0	13-0	13-0	22-0	22-0	22-0	22-0	22-0	18-0	8-0	8-0	8-0	8-0	8-0	8-0	0-8	5-0	4-0	6-4			8-0	3-0	6-0	0-4	3-0	10-0	6-5[11]	7-8	8-0	8-0
WISCONSIN	STATUTES	1951	14-0	14-0	14-0	14-0	14-0	14-0	14-0	14-0	22-0	22-0	22-0	22-0	22-0	22-0	8-6	E	8-6	8-6[2]	8-6	8-6	0-4 0-8	4-6 5-1	1-9	6-0	5-0	6-4	8-6	E	E	E	E	12-0	E	8-6	8-6	8-6
WYOMING	DOCK 9287	1959	14-0	14-0	15-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	23-6	23-0	17-0	18-0[4]	8-6	8-0	8-6	8-0	7-0[3,5]	7-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-6	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6

NOTES

THIS CHART FOR INFORMATION ONLY - NO LIABILITY CAN BE ASSUMED

ARCHITECTS, CONTRACTORS, ETC, SHOULD CHECK WITH RAILROAD INVOLVED

DIMENSIONS SHOWN IN FEET AND INCHES
ARE FOR TANGENT TRACK - MOST LAWS SPECIFY INCREASES FOR CURVED AND SUPERELEVATED TRACK
VERTICAL - MEASURED FROM TOP OF RAIL, EXCEPT CANADA - BASE OF RAIL FOR OTHER THAN PLATFORMS
HORIZONTAL - MEASURED FROM CENTER LINE OF TRACK
APPLY TO NEW CONSTRUCTION, SOME RECONSTRUCTION AND SOME EXTENSIONS.
SOME CAN BE VARIED UPON APPROVAL OF APPLICATION BY GOVERNING BODY
ARE BASED ON MAXIMUM CAR SIZE FOR ARIZONA, CALIFORNIA, IDAHO, MINNESOTA, MONTANA, NEVADA, NORTH DAKOTA, OREGON, WASHINGTON AND WEST VA
ALL ARE MINIMUM EXCEPT COLUMNS 24, 26, 28, 31 AND 33 WHICH ARE MAXIMUM

HAWAII OMITTED - NO COMMON CARRIER RAILROADS

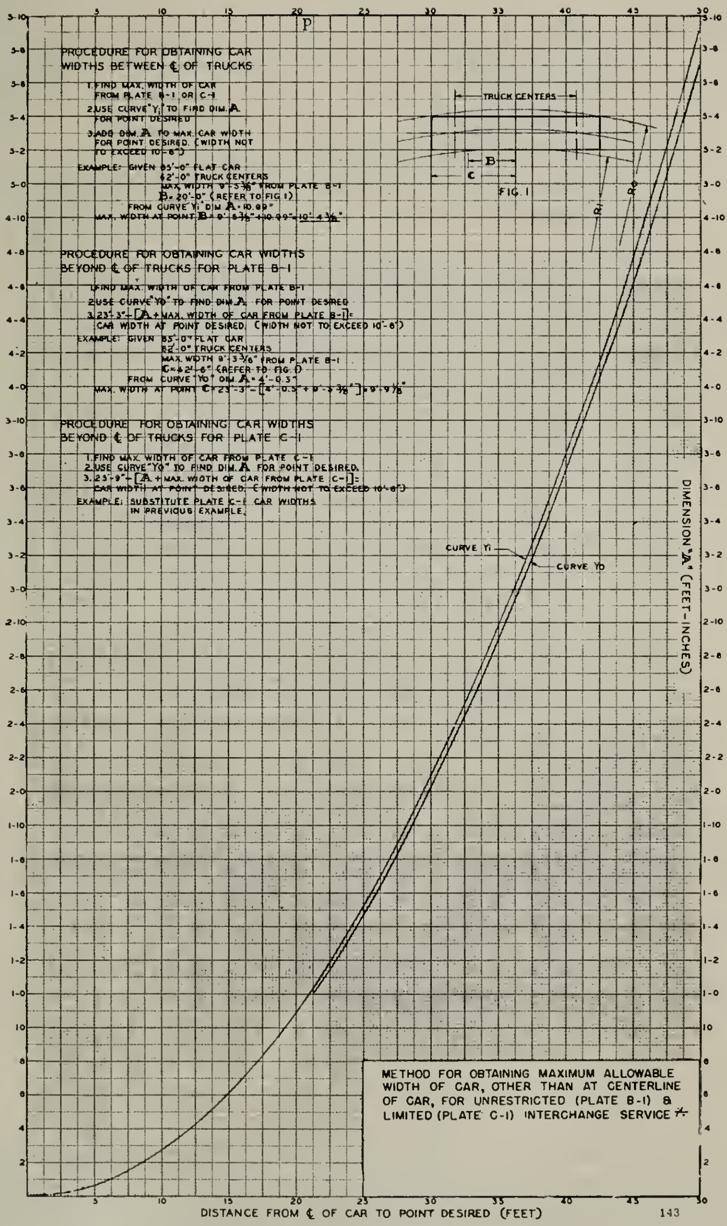
C = CONDITIONAL - SEE SPECIFIC REGULATION
CFH = CAR FLOOR HEIGHT
E = EXEMPT
H = HEIGHT OF CARS GOVERNS

COLUMN 2 SHOWS BASIC REGULATION
3 SHOWS BASIC DATE OR DATE OF LATEST AMENDMENT
7 & 8 APPLY TO HAND AND MECHANICALLY OPERATED SWITCHES EXCEPT AS NOTED
12 & 18 PREVAILS FOR ALL ITEMS NOT OTHERWISE PROVIDED FOR
13 & 19 BRIDGES SUPPORTING TRACKS
14 & 20 BRIDGES SPANNING TRACKS
24 & 25 PASSENGER PLATFORMS
26 & 27 FREIGHT PLATFORMS ON SIDE TRACKS EXCEPT AS NOTED
28 & 29 FREIGHT PLATFORMS ON SIDE TRACKS
STEPPED PLATFORMS ARE NOT GENERALLY ALLOWED
35 OTHER THAN TROLLEY CONTACT POLES
36 TO CENTER OF STAND EXCEPT AS NOTED
37 APPLIES TO BOTH SUPPORTS AND PLATFORMS EXCEPT AS NOTED

1 NO CURRENT REGULATION - CHECK WITH RAILROAD INVOLVED
2 LESSER CLEARANCES NOT PERMITTED IN QUADRANTS
3 ENGINE HOUSES AND SHOP BUILDINGS EXEMPT OR PERMITTED LESSER DIMENSIONS
4 ONLY IF TRACKS END WITHIN BUILDINGS
5 MAY BE REDUCED TO 5-9 IF 8-3 (8-6 FOR WYOMING) PROVIDED ON OPPOSITE SIDE
6 MAY BE REDUCED TO 5-9 IF 8-0 (8-6 FOR NEB & WYO) PROVIDED ON OPPOSITE SIDE
7 ONLY IF 8-0 (7-3 FOR MONT & WYO, 8-6 D.C., WASH, MASS, S.D.) PROVIDED ON OPPOSITE SIDE
8 MAY BE LESS ON ONE SIDE IF FULL GENERAL (COL 18) PROVIDED ON OPPOSITE SIDE
9 PASSENGER PLATFORMS ONLY
10 MAY BE 8-0 AT 4-6 FOR REFRIGERATOR CAR PLATFORMS ONLY
11 TO ENDS OF ARMS IN OPERATING POSITION
12 FOR PLATFORMS AT CAR EAVE HEIGHT - SUPPORTS TO BE 8-0 (8-6 FOR TEXAS)
13 FOR MAIN TRACKS - ALL OTHERS 22-0
14 8-6 FOR MAIN AND PASSING TRACKS
15 FOR FREIGHT TRACKS - CAN BE 13-0 FOR PASSENGER TRACKS
16 FOR HAND OPERATED SWITCHES - MAY BE 15-0 FOR MECHANICALLY OPERATED SWITCHES
17 FOR HAND OPERATED SWITCHES - MAY BE 17-0 FOR MECHANICALLY OPERATED SWITCHES
18 PARALLEL LEAD TRACKS 18-0
19 REGARDING CANADA - CHECK STANDARD CLEARANCE DIAGRAM, APPROVED BY BOARD OF TRANSPORT COMMISSIONERS FOR CANADA, FOR RAILWAY INVOLVED

REVISIONS
JAN 5 74
JAN 1972
JAN 1971
10-1-69
1-15-67
6-1-65
7-20-61
10-1-60

PLATE D



PROCEDURE FOR OBTAINING CAR WIDTHS BETWEEN ℄ OF TRUCKS

1. FIND MAX. WIDTH OF CAR FROM PLATE B-1 OR C-1
2. USE CURVE "Y1" TO FIND DIM. A FOR POINT DESIRED
3. ADD DIM. A TO MAX. CAR WIDTH FOR POINT DESIRED. (WIDTH NOT TO EXCEED 10'-8")

EXAMPLE: GIVEN 85'-0" FLAT CAR
62'-0" TRUCK CENTERS
MAX. WIDTH 9'-5⅜" FROM PLATE B-1
B = 20'-0" (REFER TO FIG 1)
FROM CURVE "Y1" DIM A = 10.99"
MAX. WIDTH AT POINT B = 9'-5⅜" + 10.99" = 10'-4⅜"

PROCEDURE FOR OBTAINING CAR WIDTHS BEYOND ℄ OF TRUCKS FOR PLATE B-1

1. FIND MAX. WIDTH OF CAR FROM PLATE B-1
2. USE CURVE "Yo" TO FIND DIM. A FOR POINT DESIRED
3. 23'-3" − [A + MAX. WIDTH OF CAR FROM PLATE B-1] = CAR WIDTH AT POINT DESIRED. (WIDTH NOT TO EXCEED 10'-8")

EXAMPLE: GIVEN 85'-0" FLAT CAR
62'-0" TRUCK CENTERS
MAX. WIDTH 9'-3⅜" FROM PLATE B-1
C = 42'-6" (REFER TO FIG. 1)
FROM CURVE "Yo" DIM. A = 4'-0.5"
MAX. WIDTH AT POINT C = 23'-3" − [4'-0.5" + 9'-5⅜"] = 9'-9⅛"

PROCEDURE FOR OBTAINING CAR WIDTHS BEYOND ℄ OF TRUCKS FOR PLATE C-1

1. FIND MAX. WIDTH OF CAR FROM PLATE C-1
2. USE CURVE "Yo" TO FIND DIM. A FOR POINT DESIRED.
3. 23'-9" − [A + MAX. WIDTH OF CAR FROM PLATE C-1] = CAR WIDTH AT POINT DESIRED. (WIDTH NOT TO EXCEED 10'-8")

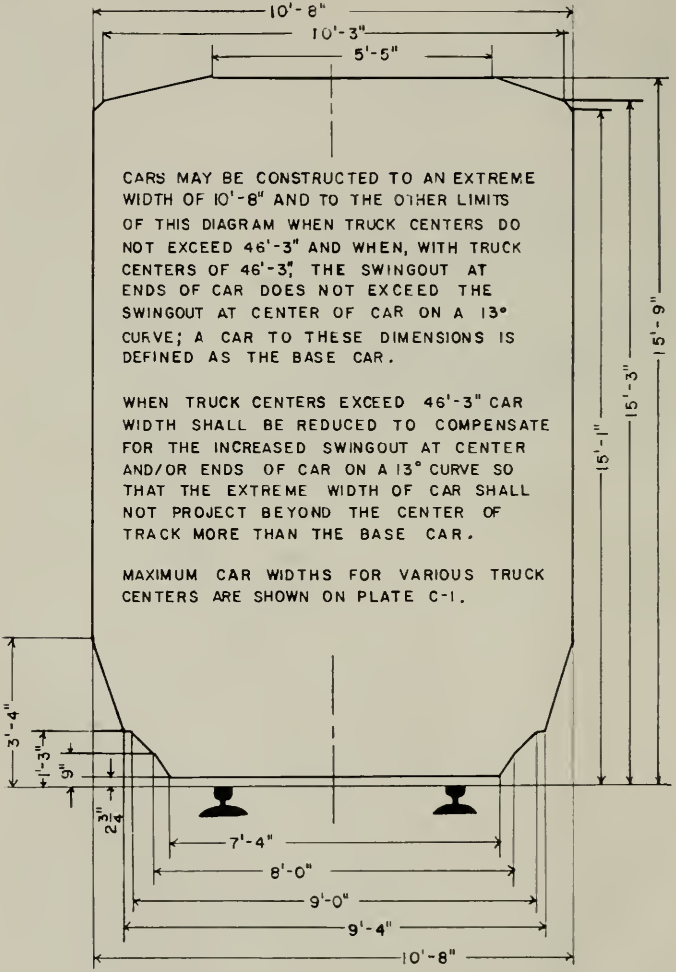
EXAMPLE: SUBSTITUTE PLATE C-1 CAR WIDTHS IN PREVIOUS EXAMPLE.

METHOD FOR OBTAINING MAXIMUM ALLOWABLE WIDTH OF CAR, OTHER THAN AT CENTERLINE OF CAR, FOR UNRESTRICTED (PLATE B-1) & LIMITED (PLATE C-1) INTERCHANGE SERVICE *

*This diagram is the same as Plate D of the Mechanical Division, AAR, and is included in the AREA Manual for convenient reference.

PLATE E

2.6 EQUIPMENT DIAGRAM FOR LIMITED INTERCHANGE SERVICE ✱



CARS MAY BE CONSTRUCTED TO AN EXTREME WIDTH OF 10'-8" AND TO THE OTHER LIMITS OF THIS DIAGRAM WHEN TRUCK CENTERS DO NOT EXCEED 46'-3" AND WHEN, WITH TRUCK CENTERS OF 46'-3", THE SWINGOUT AT ENDS OF CAR DOES NOT EXCEED THE SWINGOUT AT CENTER OF CAR ON A 13° CURVE; A CAR TO THESE DIMENSIONS IS DEFINED AS THE BASE CAR.

WHEN TRUCK CENTERS EXCEED 46'-3" CAR WIDTH SHALL BE REDUCED TO COMPENSATE FOR THE INCREASED SWINGOUT AT CENTER AND/OR ENDS OF CAR ON A 13° CURVE SO THAT THE EXTREME WIDTH OF CAR SHALL NOT PROJECT BEYOND THE CENTER OF TRACK MORE THAN THE BASE CAR.

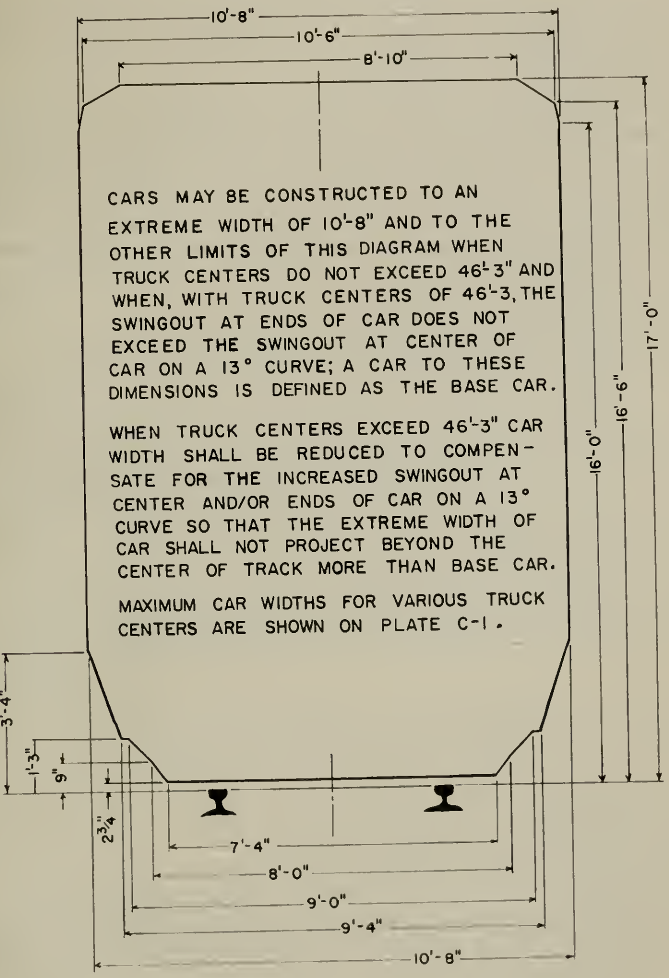
MAXIMUM CAR WIDTHS FOR VARIOUS TRUCK CENTERS ARE SHOWN ON PLATE C-1.

THE 2 3/4 ABOVE TOP OF RAIL IS ABSOLUTE MINIMUM UNDER ANY AND ALL CONDITIONS OF LADING, OPERATION, AND MAINTENANCE.

✱ THIS DIAGRAM IS THE SAME AS PLATE E OF THE MECHANICAL DIVISION, AAR, AND IS INCLUDED IN A.R.E.A. MANUAL FOR CONVENIENT REFERENCE. FOR RESTRICTIONS APPLICABLE TO THIS DIAGRAM SEE "RAILWAY LINE CLEARANCES".

PLATE F

2.7 EQUIPMENT DIAGRAM FOR LIMITED INTERCHANGE SERVICE *



CARS MAY BE CONSTRUCTED TO AN EXTREME WIDTH OF 10'-8" AND TO THE OTHER LIMITS OF THIS DIAGRAM WHEN TRUCK CENTERS DO NOT EXCEED 46'-3" AND WHEN, WITH TRUCK CENTERS OF 46'-3, THE SWINGOUT AT ENDS OF CAR DOES NOT EXCEED THE SWINGOUT AT CENTER OF CAR ON A 13° CURVE; A CAR TO THESE DIMENSIONS IS DEFINED AS THE BASE CAR.

WHEN TRUCK CENTERS EXCEED 46'-3" CAR WIDTH SHALL BE REDUCED TO COMPENSATE FOR THE INCREASED SWINGOUT AT CENTER AND/OR ENDS OF CAR ON A 13° CURVE SO THAT THE EXTREME WIDTH OF CAR SHALL NOT PROJECT BEYOND THE CENTER OF TRACK MORE THAN BASE CAR.

MAXIMUM CAR WIDTHS FOR VARIOUS TRUCK CENTERS ARE SHOWN ON PLATE C-1.

THE 2¾ ABOVE TOP OF RAIL IS ABSOLUTE MINIMUM UNDER ANY AND ALL CONDITIONS OF LADING, OPERATION, AND MAINTENANCE.

* THIS DIAGRAM IS THE SAME AS PLATE F OF THE MECHANICAL DIVISION, AAR, AND IS INCLUDED IN A.R.E.A. MANUAL FOR CONVENIENT REFERENCE. FOR RESTRICTIONS APPLICABLE TO THIS DIAGRAM SEE "RAILWAY LINE CLEARANCES".

Manual Recommendations

Special Committee on Concrete Ties

J. R. Williams *(chairman, committee)*, R. J. Brueske, K. C. Edscorn, W. E. Fuhr, C. L. Gatton, M. B. Hansen, D. L. Jerman, T. C. Netherton, E. L. Robinson, G. H. Way, J. W. Weber.

Your committee recommends for adoption and publication in Chapter 3 of the Manual the Specifications for Concrete Ties (and Fastenings) published in AREA Bulletin 644, September–October 1974, pages 84 through 131, with the following revisions:

Page 86 Definition 5—At end of sentence add "and perpendicular to the rail."
Page 86 Definition 10—Change second sentence to read: "Under design loads the tensile strength of the concrete in the tension faces of the tie is not exceeded."
Page 86 Definition 11—Change second sentence to read: "If cracks do occur, the resulting crack widths do not exceed specified values."
Page 86 Definition 17—Change second sentence to read: "Under design loads the tensile strength of the concrete in the tension faces of the tie is exceeded; however, the resulting crack widths do not exceed specified values."
Page 87 6.1.1—In first line delete the words "train weight."
Page 87 6.1.1—In the sixth line change the word "new" to "different."
Page 88 6.1.2.4—Change last sentence to read: "An impact factor of 150% has been assumed."
Page 90 6.1.2.5.1.1—In line 12, change sentence to read: A = Bearing area of cross ties in square inches.
Page 90 Asterisk for 6.1.2.5.1.1—Delete "with bearing length of 33 inches on each end of ties." Change last three lines of computations to read:

$$= \frac{60{,}000\ (2.5)\ (.57)}{10 \times 12}$$

$$= 69.9 \text{ psi}$$

Page 92 6.1.5.1—In line 1, show division line in $S = \frac{M_c}{I}$
Page 93 6.2.3.1—In second sentence, insert "strand and" between "stress-relieved" and "wire."
Page 94 6.2.3.2—In line 2, delete "in psi."
Page 94 6.2.3.3—Place colon at the end of line 4.
Page 96 6.2.4.2—Change second sentence to read: "Values for the following ASTM test method specifications are under study:"
Page 100 6.4.2.2—Change to read: "It is recommended that the maximum precompression after all losses at any point in the cross ties should not exceed 2.500 psi."
Page 106 6.9.1.10—Change third sentence to read: "The load *P* (measured load plus unsupported tie weight plus frame weight) at which separation of the rail . . . etc."
Page 106 6.9.11—Paragraph (b) line 6—after the word "cycles" add "the rail shall be free to rotate under the applied loads."
Page 107 6.9.1.12—In line 7, change 1/10,000 th to 1/1,000 th; in line 10, change "6.6.2" to "6.6.1."
Page 107 6.9.1.13—Delete and substitute the following revised 6.9.1.13.

6.9.1.13 Lateral Load Restraint Test

With a suitable length of new rail of the size to be used in the track affixed to the tie block in a manner appropriate to the fastening being used, the entire assembly is supported and loaded as shown in Figure XI. The loading head is to be fixed against translation and rotation. The wood block shall be 10-in x 10-in x ¾-in thick, 5 ply, exterior grade plywood.

(a) A preload of 20 kips is to be applied to the rail to seat the rail in the fastening. Upon release of the preload, a zero reading is to be taken on the dial indicators which measure rail translation. Load is to be applied at a rate not to exceed 5 kips per minute until either 41 kips has been applied or the rail base has translated ⅛ inch, whichever occurs first. Inability of the fastening to carry the 41 kip load with ⅛ inch or less of rail translation shall constitute failure of this test. Complete failure of any component of the tie or fastening is cause for rejection.

(b) With all load removed from the rail, a roller nest is placed between the fixed loading head and the wood block on the rail head. The roller nest shall not offer resistance to lateral movement of the rail head. After taking zero readings on the dial indicators, which measure gage widening and rail translation, a load of 20.5 kips is to be applied at a rate not to exceed 5 kips per minute. Rail rotation, gage widening less rail translation, greater than ¼ inch shall constitute failure of this test.

Page 113 6.11.4—Delete the word "requirements", change 6.11.4 to 6.11.5.

Page 113 & 114 6.11.5—Change to 6.11.4 including all sub-paragraphs and place before "tamping" paragraph.

Page 114 6.12.1—At the end of the sentence add the following: "The most successful concrete tie installations to date have used sound granite, trap rock, or similar types of ballast and such types of ballast are, therefore recommended for use in conjunction with concrete ties. Current and proposed research may indicate that other ballast materials also could be satisfactory."

Page 115 6.12.2.2—Change to read as follows: "The percentage of wear shall not be greater than 30% when tested in a Los Angeles rattler in accordance with ASTM designation C 535 or C 131, whichever is applicable to the size of the ballast."

Page 115 6.12.2.4—Delete and substitute the following: "The subject of hardness is under study."

Page 115 6.12.2.5—Delete and substitute the following: "The subject of water absorption is under study."

Page 116 6.13.12—Change tie spacing and rail seat loads to read as follows:

Spacing, Inches	*Rail Seat Load, Pounds*
30	61,500
27	57,050
24	52,600
21	48,150

Page 118 6.13.3.1—Line 16 solving for *R*., change to read as follows:

$$R = \frac{F^2S}{2\ \text{DAE}} = \frac{35{,}870{,}087{,}236\ S}{291{,}375{,}000} = 123.1\ S$$

In fifth line from bottom, change to read as follows: S = 21 inches, 24 inches, 27 inches, 30 inches.

Page 118 6.13.3.2—After first sentence add "This force is approximately 10 kips." Delete last sentence: "Using Cooper E 80 etc. . . . ."

Page 123 Figure III—In the left hand corner after the word "tie" in "M = positive moment at the center of the tie" add "as required in Table I".

Page 125 Figure V—Delete *P* at load arrows.

Page 127 Figure VII—In upper right hand corner change to read "M = negative moment at the rail seat as required in table I or Table II".

Page 131 Figure XI—Delete ± 3°

Manual Recommendations

Committee 15—Steel Structures

Report on Assignment B

Revision of Manual

D. L. Nord *(chairman, Subcommittee on Revision of Manual)*, A. J. Wood *(chairman, Subcommittee on Welded Steel Railway Bridges)*, D. S. Bechly, A. B. Belfield, Jr., E. S. Birkenwald, E. Bond, T. J. Boyle, J. C. Bridgefarmer, H. L. Chamberlain, A. C. Danks, H. E. Dearing, J. L. Durkee, G. F. Fox, G. K. Gillan, K. H. Lenzen, R. C. McMaster, G. E. Morris, T. J. Mearsheimer, D. V. Messman, R. D. Nordstrom, F. D. Sears, M. Schifalacqua, J. E. Stallmeyer, E. S. Thoden, R. N. Wagnon, C. R. Wahlen.

Your committee submits for adoption the following recommendations with respect to Chapter 15 of the Manual:

Pages 15–1–1 to 15–1–38, incl.

PART I—DESIGN—ASTM A 36 STEEL

On page 15–1–3, add new Article as follows:

1.1.8 Design of Public Works Projects

(a) The design, plans, special provisions and specifications for railroad bridges to be built as a public works project and paid for with public funds administered by a public agency shall be prepared by the engineering staff of the railroad involved or by a consulting engineer whose selection has been mutually approved by the railroad and the public agency. The intention of this requirement is that if a consultant is selected, it shall be one who is familiar with the design of railroad bridges, and particularly with the special requirements and operating conditions of the railroad concerned so that the time involvement of the railroad's engineering staff will be minimized.

(b) If a consulting engineer is engaged, the contract for his services may be administered by the public agency or by the railroad if it so desires. In either case, the technical aspects of the work of the consulting engineer shall be under the direction of the railroad and the final plans and specifications must meet with the approval of the railroad.

On page 15–1–11, revise Article 1.3.9 to read as follows:

1.3.9 Lateral Forces from Equipment

(a) A single moving concentrated lateral force equal to ¼ of the weight of the heaviest axle in the specified design live load shall be applied at the base of rail in either direction and at any point along the span in addition to the other lateral forces specified. On spans supporting multiple tracks, the force shall be applied on one track only.

(b) The only resulting stresses to be considered are axial stresses in members bracing the flanges of stringer, beam and girder spans, the chords of truss spans and in members of cross frames of such spans, and stresses from lateral bending of flanges of longitudinal flexural members having no bracing system. The effects of lateral bending between braced points of flanges, axial forces in flanges, vertical forces and forces transmitted to bearings shall be disregarded.

Pages 15–3–1 to 15–3–17, incl.

PART 3—FABRICATION

On page 15–3–4.1, add the following new Article 3.1.7.2:

3.1.7.2 Special provisions for trusses and viaduct-tower main members

(a) Abutting joints of compression members which have been faced for bearing, when assembled, shall have a minimum of 70% of the main material bearing area in contact. Any element of the main material shall have a minimum of 60% of its bearing area in contact. The maximum gap for portions not in contact shall be 0.03 inch. A gap not exceeding 0.005 inch qualifies as contact.

Note: Refer to Art. 3.1.13 for surface texture requirement.

(b) For member connections or splices, whether at joints or between joints, the clearance between the in-to-in dimension of the gusset plates or splice plates and the out-to-out dimensions of the entering member shall not exceed $\frac{3}{16}$ inch or as otherwise indicated by the engineer for joints with thick or multiple gusset plates, long diaphragms, or other special framing conditions.

(c) The use of squaring-up diaphragms may be necessary to meet the tolerances established in Arts. 3.1.7.1 and 3.1.7.2. Design details of squaring-up diaphragms and any design restrictions on their use shall be shown on the design plans. Unless designated otherwise, their use will be optional with the fabricator. All squaring-up diaphragms shall be shown on the shop plans.

On page 15–3–15, add to Art. 3.4.1 a new Paragraph (d) reading as follows:

(d) Weathering steel, ASTM A 588, need not be shop-painted provided the shop painting requirement is waived in the contract documents or is otherwise deleted by the engineer.

Pages 15–4–1 to 15–4–8, incl.

PART 4—ERECTION

On page 15–4–6, add to Section 4–24 a new Paragraph (e) reading as follows:

(e) Weathering steel, ASTM A 588, need not be field painted provided the field painting requirement is waived in the contract documents or is otherwise deleted by the engineer.

Your committee also submits the following editorial revisions to Parts 1 and 2 of Chapter 15.

On Page 15–1–6, Revise Article 1.2.10 to read:

1.2.10 Name Plates

(a) A name plate showing in raised letters the name of the fabricator and the year of construction shall be attached to one end of each span at a point convenient for inspection.

Revise the Appendix to Part 1 as follows:

On page 15–1–37, change the center shear values for spans of 18, 20 and 24 ft from 27.77, 28.00 and 31.67 to 28.89, 28.70 and 31.75, respectively.

On page 15–1–38, change the limits of the first and last formulas from 284 and 142 to 288 and 144, respectively.

On page 15–1–13, Article 1.3.13.3.1 add the following at the end of the first sentence:

", and at fillet welds connecting stiffeners to webs of girders."

On page 15–2–5, Article 2.3.1.3.1 add the following at the end of the first sentence:

", and at fillet welds connecting stiffeners to webs of girders."

On page 15–1–14, Article 1.3.13.3.3 (b) add the following at the end of the first sentence:

"and other than at stiffeners to webs of girders:"

On page 15–2–6, Article 2.3.1.3.3 (b) add the following at the end of the first sentence:

"and other than at stiffeners to webs of girders:"

On page 15–1–33, Article 1.10.10 (b) delete the word "tensile" in the first line.

Report on Assignment 10

Continuous Welded Rail on Bridges

Collaborating with Committee 4

R. I. Simkins *(chairman, subcommittee)*, H. L. Chamberlain, J. W. Davidson, H. E. Dearing, C. A. Hughes, D. V. Messman, R. D. Nordstrom, A. L. Piepmeier, H. Solarte, Wm. Wilbur, M. O. Woxland.

Your committee submits for adoption the following new Section 8.3 to be added to Part 8 of Chapter 15.

8.3 ANCHORAGE OF DECKS AND RAILS ON STEEL BRIDGES

8.3.1 Foreword

(a) Because of lack of research data, there is no way accurately to predict the behavior of rail on bridges under the influence of temperature changes, braking and traction of trains, and creep. The recommendations which follow are based on experience.

8.3.2 Anchorage of Decks to Bridge Spans

8.3.2.1 Open-deck bridges

(a) Ties shall be anchored to bridge spans to control lateral, vertical and longitudinal movement. Each anchorage shall consist of two fasteners, each of cross-sectional area not less than that of a ¾-inch-diameter bolt. Maximum longitudinal anchorage spacing shall be 4 ft 6 inches.

(b) Where hook bolts are used for anchorage of ties, the ties shall be dapped to fit the top flanges of the girders or stringers or suitable lateral restraining devices installed as required. Such tie daps shall not be less than ½ inch deep nor more than ½ inch wider than girder or stringer flange.

(c) A guard timber of section not less than 4 inches by 8 inches nominal, or a metal spacer plate, shall be placed on the deck outside of each rail and secured to each tie with lag bolts or drive spikes of not less than ⅝ inch diameter.

8.3.2.2 Ballast-deck bridges

(a) Wooden ballast decks, and precast concrete slab decks, shall be anchored to bridge spans with fasteners having total capacity equivalent to that specified for open decks.

(b) Cast-in-place concrete decks shall be anchored to steel spans either by shear connectors or by making the bottom of the concrete slab flush with the bottom surface of top flanges of girders or stringers.

8.3.3 Anchorage of Rail

8.3.3.1 Lateral and vertical rail anchorage

(a) Tie plates and spikes shall be considered adequate as lateral and vertical anchorage of rails to wooden ties.

8.3.3.2 Anchorage of rail to concrete slabs, concrete ties, or directly to steel spans

(a) Such fastening systems are special applications and shall be approved by the engineer.

8.3.3.3 Longitudinal anchorage of conventional jointed rail

(a) Rail anchors shall be installed as specified by the engineer.

8.3.3.4 Longitudinal anchorage of continuous welded rail without expansion joints or bolted joints

(a) On bridges with total length less than 300 ft, rail anchors need not be used; but on both roadbed approaches the rail shall be box-anchored longitudinally at each tie for a distance of 200 ft.

(b) On bridges with total length of 300 ft or greater, rail anchors shall be applied as follows:

(1) For individual spans of 100 ft or less, rail anchors shall be applied throughout the span, at all ties anchored to bridge spans.
(2) For individual spans exceeding 100 ft, rail anchors shall be applied only in the first 100 ft from the fixed end, at all ties anchored to bridge spans.

(c) Forces in continuous welded rail may be computed from the following equations:

$$I.F. = 38\,WT$$
$$R.F. = \frac{WDT}{150}$$

where

$I.F.$ = internal force in 2 rails, in pounds; compression for temperature rise, tension for temperature fall;

$R.F.$ = radial force in 2 rails, in pounds per foot of bridge; acting toward outside of curve for temperature rise, toward inside for temperature fall;

W = weight of one rail, in pounds per yard;
T = temperature change in degrees F;
D = degree of curvature.

8.3.3.5 Longitudinal anchorage of continuous welded rail with expansion joints

(a) Rail anchors shall be applied to secure the fixed parts of rail expansion joints.

(b) Rail anchors shall be applied at the center of rail strings having movable parts of rail expansion joints at the ends.

8.3.4 Rail Expansion Joints

(a) Movement of rail due to changes in temperature or to train action sometimes produces adverse effects. The magnitudes of the movement and of the resulting forces are difficult to forecast. In order to reduce the likelihood of rail breakage, to relieve rail radial forces where they cannot feasibly be resisted, and to facilitate track maintenance where track and fastenings must be disturbed, rail expansion joints may be used.

8.3.4.1 Moveable spans

(a) In addition to the rail joints that provide for expansion and contraction of the movable span and its rails, consideration shall be given to placing one pair of rail expansion joints immediately off each end of the span.

8.3.4.2 Long-span bridges

(a) For individual simple bridge spans of 300 ft or greater, rail expansion joints shall preferably be used at or near the expansion end of the span, as specified by the engineer.

8.3.4.3 Open-deck bridges on curves with continuous welded rail

(a) Rail expansion joints shall preferably be used for each bridge having total length greater than 50 ft located on curve exceeding 2 deg. If feasible, the joint location should be off the curve.

8.3.4.4 Number and positioning of rail expansion joints on bridges with continuous welded rail

(a) Rail expansion joints shall be used in pairs, which shall be installed closely or directly opposite each other, depending on the type of joint used.

(b) Where two pairs of joints are used, they shall preferably be located near the center of bridge.

(c) Where an even number of pairs of expansion joints is used greater than two pairs, they shall preferably be placed in groups of two pairs, with the fixed parts of one pair connected to the fixed parts of the other pair.

(d) Where an odd number of pairs of expansion joints is used, the odd pair shall preferably be at one end of bridge, and either entirely on or off the bridge. In the absence of other controlling conditions, the odd pair shall preferably be at the lower end of a bridge on grade and the remaining pairs shall be placed as in (c).

(e) The spacing and design of joints shall be such that the maximum length L in feet of rail causing movement through each joint shall be as follows, except that L shall not exceed 1500 ft.

$$eLT = \frac{(J - K_1)}{12\,K_2} \quad \ldots\ldots\ldots\ldots \quad (8.1)$$

where

e = coefficient of rail thermal expansion = 0.0000066;

T = temperature range, in degrees F (140 deg recommended in the absence of a substantiated value);

J = total permissible range of movement in the joints, in inches;

K_1 = creep allowance, in inches (3 inches recommended in the absence of a substantiated value);

K_2 = safety factor (1.5 recommended).

For the recommended values, formula (8.1) reduces to

$$L = (J - 3)\ 60 \qquad (8.2)$$

or

$$J = \frac{L}{60} + 3 \qquad (8.3)$$

(f) Rail expansion joints shall be assembled in such a manner that they are at the approximate midpoint of the range of movement at a temperature midway between the expected extremes.

(g) The design and details of rail expansion joints shall be such as to minimize resistance to expansion and contraction.

8.3.5 Supplemental Requirements for Continuous Welded Rail Having Bolted Joints

(a) For bridges where no rail expansion joints are provided, rail anchorage shall be provided on the approach roadbeds as necessary to supplement rail-joint tension capacities.

(b) Regular bolted rail joints may be used on bridges protected by rail expansion joints, provided that such regular joints are in stretches of rail wherein thermal expansion and contraction are free to occur, and that provision is made for the expected longitudinal movements of the regular rail joints to occur without any fouling.

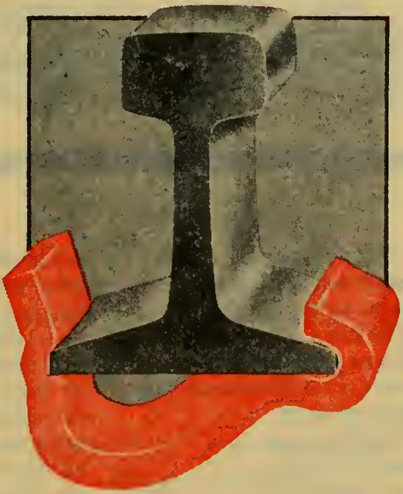
8.3.6 Maintenance of Bridges with Continuous Welded Rail

(a) Suitable measures shall be taken to prevent buckling of tangent track or rails during maintenance operations. The most favorable rail temperatures for such work are those below that of the rail when it was laid. The probability of rail compression resulting from creep and other causes shall be considered.

(b) On curved track, the effect of radial forces shall be considered and measures taken to hold the track in line during maintenance operations. Work shall not be done during periods of extreme high or low temperatures.

(c) Maintenance operations involving removal of fastening of rail to ties or ties to bridge steel shall be carried out in short sections; and, if practicable, on alternate ties in a first phase and on the remaining ties in a second phase.

STOP!
THINK UNIT



No overdriving

Effective on worn rail as well as new rail

Longer service life without shimming or reforming

No throat cutting of spikes

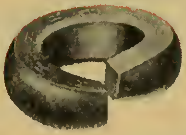
Suitable for machine or hand application

More Holding Power

Higher reapplication value

Less likelihood of damage to rail or anchors from derailed wheels

ALSO AVAILABLE—UNIT II. Same high quality at a lower cost . . . Made from a slightly lighter section of steel, for requirements where the very high holding power and reserve strength of the Standard Unit are not considered essential.



Hubbard Super Steel and Super Service Alloy TRACK SPRING WASHERS . . . manufactured to meet all current A.R.E.A. specifications.

74UR1-A

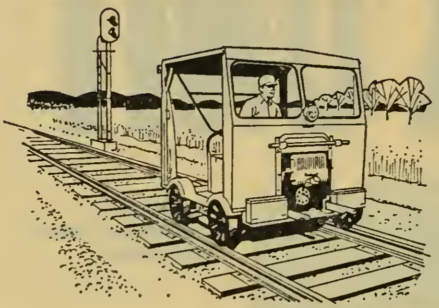
MEMBER RPI RAILWAY PROGRESS INSTITUTE

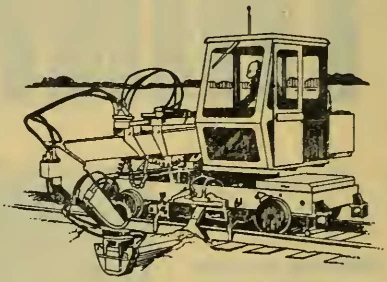
UNIT RAIL ANCHOR COMPANY

P.O. Box 4004
Pittsburgh, Pa. 15201
(412) 781-4800

Midwest Office: 332 S. Michigan Ave.
Chicago, Ill. 60604
(312) 427-7442

Fairmont
RAILWAY MOTOR CARS
AND WORK EQUIPMENT





INSPECTION MOTOR CARS
SECTION MOTOR CARS
GANG MOTOR CARS
PUSH CARS AND TRAILERS
HY-RAIL EQUIPMENT
BALLAST MAINTENANCE CARS
WEED MOWERS
MOBILE CRANES
TOW TRACTORS
RAIL GRINDERS
DERRICK CARS
HYDRAULIC POWER TOOLS
TRACK LINERS
TRACK LINING LIGHT
SPIKE DRIVERS
TIE REMOVERS
TIE HANDLERS
RAIL LIFTERS
TIE SHEARS
TIE BED SCARIFIERS
SPIKE PULLERS
TIE PLUG INSERTERS
OIL SPRAYERS
TIE SPRAYERS
TIE INSERTERS

Performance
ON THE JOB
COUNTS

THESE UNITS ARE ACTUATED EITHER COMPLETELY
OR PARTIALLY BY HYDRAULIC POWER

FAIRMONT RAILWAY MOTORS, INC., FAIRMONT, MINNESOTA 56031

VELSICOL®

"THE NEW FORCE IN VEGETATION CONTROL CHEMICALS"

BANVEL®

The 3 E's herbicide

Efficacy—Banvel is a systemic.

Economy—Long-lasting and low cost.

Ecology—Relatively short persistence—established tolerances for many food crops and milk.

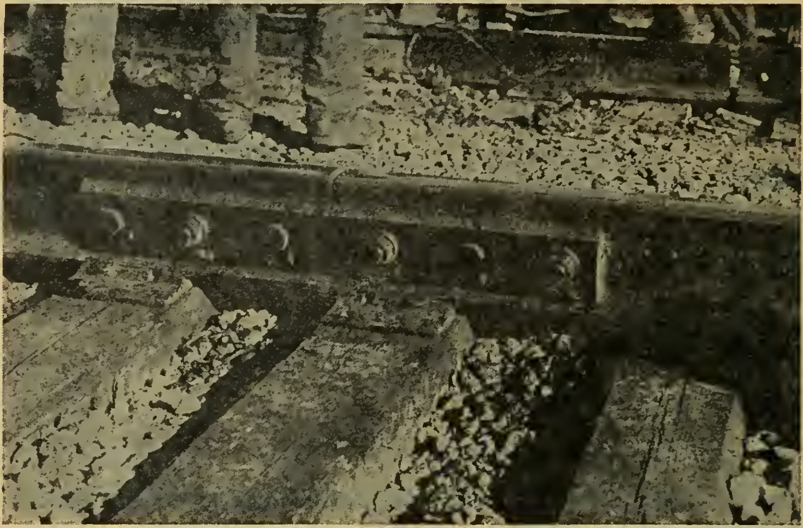
VEGATROL™

A full line of 2,4-D's and 2,4,5-T together with the Banvel line of herbicides, answers your unwanted Vegetation Problems.

ACCUTROL™ air emulsion SPRAY SYSTEM

- Low-volume Spraying
- Drift Reduction

VELSICOL CHEMICAL CORPORATION
341 East Ohio Street
Chicago, Illinois 60611



The Allegheny Insulated Rail Joint-

Designed to withstand the heaviest traffic in welded rail

This modern joint cements rail ends in position and thereafter resists all forces imposed by temperature and simultaneous forces of live loads to move them.

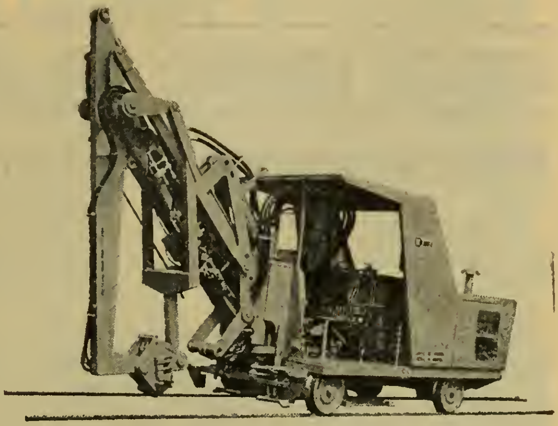
This joint makes welded rail truly continuous. It promises you years of service without maintenance costs. It reduces rail and wheel batter to a previously unknown minimum. It employs the safety of steel splice bars. It can be assembled in the shop or field. It has been tested in service and AAR laboratories. It saves you lots of money.

Allegheny Drop Forge Company

Subsidiary of Tasa Corporation

2707 Preble Avenue • Pittsburgh, Pa. 15233

When it comes to RAILWAY MAINTENANCE EQUIPMENT



We believe . . .

it is the responsibility of the manufacturer to design, build and operate if required, the equipment that will do the job easier, quicker and at less cost. Whether purchased, rented or leased, the equipment must justify the cost by performance . . . be safe in operation and travel . . . and make maximum use of track time schedules. Such a unit is the

MANNIX WOOD OR CONCRETE TIE INSERTER

Diesel powered with full view push button operation that enables one man to complete a full cycle (move and locate machine, pick tie off rails and insert) in as little as 12 seconds from either side. Boom is swung forward between rails in travel. Air operated brake shoes on all wheels. Hydraulic powered turn table set-off is standard equipment.

MEMBER RPI RAILWAY PROGRESS INSTITUTE

MANNIX RAILWAY MAINTENANCE EQUIPMENT FOR:
• Shoulder Ballast Cleaning • Raising Track • Resurfacing • Reballasting • Replacing Ties • Undercutting • Ballast Cleaning • Rail Grinding Single or Multiple track—Mainline or Yard tracks
CONTRACT, SALE or LEASE

FOR FULL DETAILS, OR SHOWING OF OPERATING FILMS, WRITE OR CALL TODAY

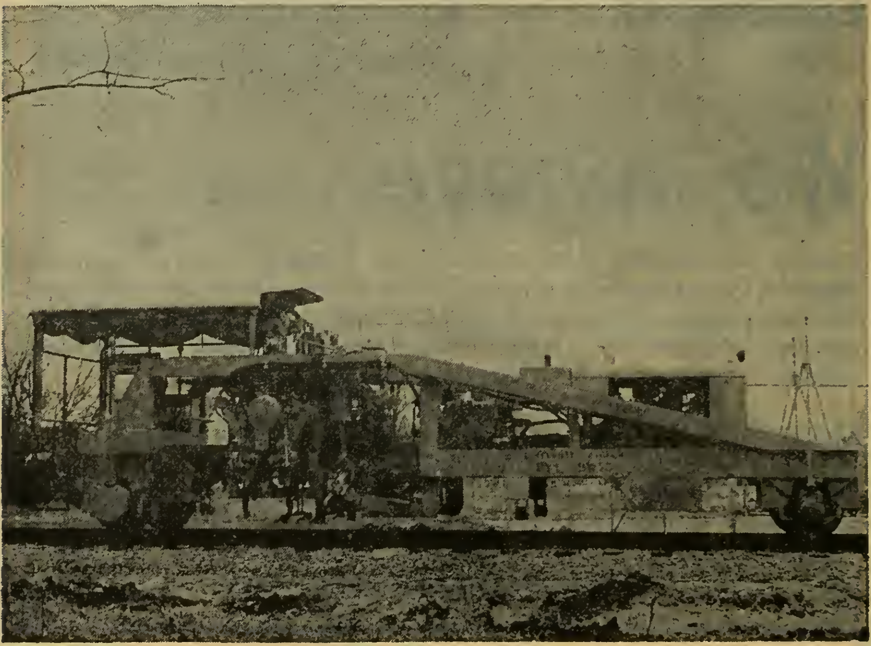
MANNIX

MAINTENANCE of WAY DIVISION
MANNIX CONSTRUCTION, INC.
3900 Arrowhead Road, Hemel, Mn 55340, U.S.A.
Phone (612) 478-6014
Telex 29-0391; Cable, MANNIX

SWITCH TAMPERS FOR ALL YOUR JOBS

UNIVERSAL UYT-2W75 YARD, SWITCH & SPOT TAMPER

This versatile tamper is a new addition to the popular Plasser Universal line. Even though the UYT 2W75 has a lower original cost, it is equipped with two of the exclusive Plasser four-tool tamping heads with individually tiltable tamping arms, which insures the tamping of every tie through switches and turnouts without the use of outside or ground jacks.



This Universal UYT 2W75 tamper is particularly adaptable for yard work where it has proven itself as a money saver. The reasonable price plus its ability to do a fine job tamping switches and doing spot work suggest yard assignment. It can be equipped with automatic lifting and leveling equipment as well as automatic lifting correction with cross level indicator. You should see one of these tampers in service and we will be pleased to make the necessary arrangements for you to do so at your convenience. You will be convinced that it is a superior machine.

PLASSER AMERICAN CORPORATION

PLASSER FOR PERFORMANCE

GENERAL OFFICES & PLANT
2001 MYERS ROAD
CHESAPEAKE, VIRGINIA 23324

Upgrading Timber Bridges?

OSMOSE INSPECTION

can help your timber bridges carry heavier loads and last longer with minimum repair

This professional Osmose team is cruising one of 202 timber bridges on a subdivision of a major U.S. Railroad. On completion, specific recommendations were given the chief engineer to treat, defer or replace, backed up by detailed boring records. This is one more way Osmose assures you that maintenance dollars are spent where needed most.. without cost or obligation to your company.

OSMOSE RAILROAD DIVISION
4915 MONONA DRIVE • MADISON, WIS. 53716

TIE HANDLER from RTW...

with 24-foot-reach articulating boom!

Lifting capacity—1500 lbs. at 12′6″ to 750 lbs. fully extended.

- **New rotating deck design ...no adjustments needed**
- **Thermostatic controlled oil temperature in hydraulic circuit**
- **Low maintenance**
- **Hydrodynamic plus mechanical brakes... on all four wheels**

Many other features for high production, low maintenance. Choice of two other tubular-type booms (all interchangeable): Fixed 24-ft., and manually adjustable 18-24-ft. From RTW, the people with the longest experience in tie handling. Get full details today. Call (215) 739-4281.

RTW

OTHER RTW MAINTENANCE EQUIPMENT • Switch Grinders • Cross Grinders • Surface Grinders • Rail Drills • Tie Handlers
RAILWAY TRACK-WORK CO. 2560 East Tioga St., Philadelphia, Pa. 19134
Agents: Chicago – ESCO Equipment Service Co. • Houston – Service Equipment & Supply Company
Los Angeles – Simkins Company • Louisville – T. F. Going • St. Louis – R. E. Bell Co.
S. Plainfield, N. J. – Eastern Railroad Equipment Corp. • Canada: Montreal – Woodings-Canada Ltd.

MEMBER RPI
RAILWAY PROGRESS INSTITUTE

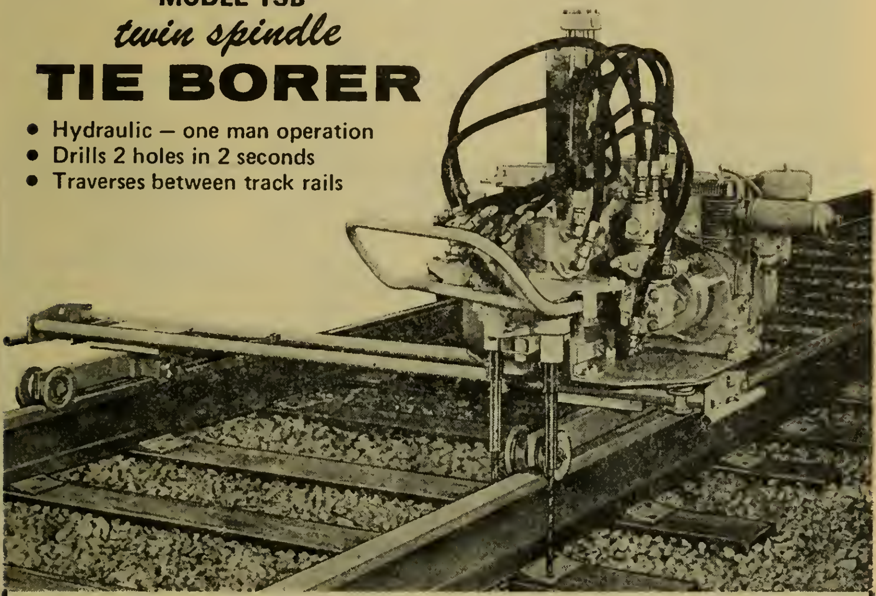
Safetran

MODEL TSB

twin spindle

TIE BORER

- Hydraulic — one man operation
- Drills 2 holes in 2 seconds
- Traverses between track rails



The Model TSB Twin Spindle Tie Borer is designed to drill fast, accurate holes for either screw or cut spikes. The unit is compact, efficient and easily operated by one man. Design features assure rapid automatic operation that drills holes which are vertical and accurately centered to the controlled correct depth. Drill spacing adjustments can be quickly made, because of the absence of drive belts and idlers. The drilling cycle is hydraulically operated by applying up or down pressure to the control handle which raises and lowers the two drills. The drilling unit is traversed hydraulically on its carriage from one rail to the other allowing one operator to push the unit and perform all operations.

For operating data and specifications
see your SAFETRAN CATALOG — Section 16-A

Safetran Systems Corporation
7721 National Turnpike • Louisville, Ky. 40214 • (502) 361-1691

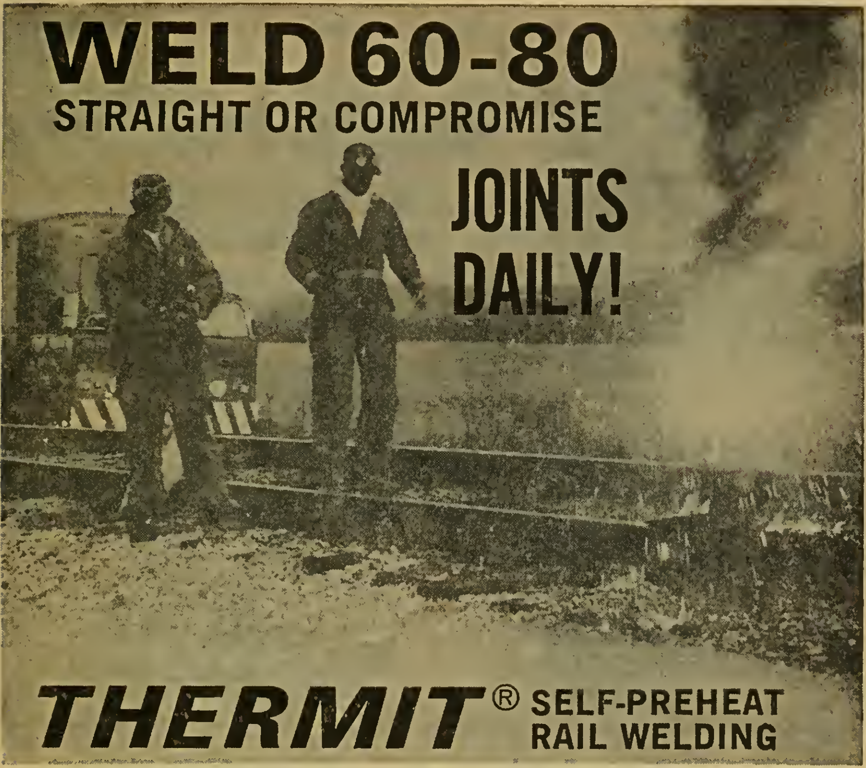
A tradition of service . . .

- **Water Treatment Chemicals Protecting Diesel Cooling Systems and Steam Generators**
- **Fuel Oil Additives**
- **Pollution Control Chemicals and Consulting Services**

NALCO CHEMICAL COMPANY
2901 BUTTERFIELD ROAD • OAK BROOK, ILLINOIS 60521

NALCO Trademarks of Nalco Chemical Company

NALCO



THE MODERN IN-TRACK METHOD

- AUTOMATIC, **ERROR-FREE** PRE-HEATING AND TAPPING OF WELD METALS
- EASY, **COLD** REMOVAL OF RISERS
- MINIMUM GRINDING
- NO EQUIPMENT TO PURCHASE OR LEASE

FREE COMPLETE THERMIT RAIL WELDING DETAILS **PLUS** JOB-SITE DEMONSTRATIONS.

WRITE OR CALL

THERMIT®

THERMEX METALLURGICAL, INC.
LAKEHURST, N. J. 08733 • (201) 657-5781
SALES OFFICES IN MAJOR CITIES

HABCO Satisfaction through service

Specialists and manufacturers in the field of vegetation control.

SOIL STERILANTS
GRANULES—HABCO HYCHLOR . . . HABCO 5H . . . HABCO 10K . . . HABCO 10T . . . HABCO BROMEX
LIQUIDS —CHLORATE-BORATE . . . HYVAR X . . . KARMEX . . . TELVAR . . . ATRATOL . . . PRAMITOL

CONTACT CHEMICALS
DACONATE . . . DACAMINE . . . 2,4-D's OF ALL KINDS

BRUSH CONTROL
AMMATE . . . HABCO 10B . . . ALL COMBINATIONS OF 2,4-D and 2,4,5-T

YOUR APPLICATION OR OURS

HABCO INCORPORATED

Our regional representatives are as close as your telephone.

D. DOUGLAS BOATRIGHT
Room 604, Transportation Bldg.
Birmingham, Ala. 35203
205/252–6715

DONALD E. HORNE
JOHN A. FELLMAN
7301 W. Lake St.
Minneapolis, Minn. 55426
612/929-4689

DON TELGE
JOHN FORDERHASE
2251 Armour Road
North Kansas City, Mo. 64116
816/421-1488

ROBERT E. LUND
1040 Coulter
Winnipeg 3, Manitoba
204/783-3684

no matter how
you look at it
there is just
one toilet
that stands alone.
one toilet that
has gained
general acceptance
world wide.
one toilet familiar
to all who have ever
flown in an airplane,
traveled in a bus,
sailed in a boat,
or lived in a recreational vehicle.
the one chemical
retention toilet
now available,
designed especially

to recognize
the rugged requirements,
for all your
sanitation needs:
locomotive
caboose
work equipment . . .
the Vapor NEWMATIC* toilet,
the toilet used
by more than 40 railroads**
become *more* familiar,
write
Transportation Systems Div.
Vapor Corporation
6420 West Howard Street
Chicago, Illinois 60648
In Canada—
Vapor Canada Limited

VAPOR CORPORATION
TRANSPORTATION SYSTEMS DIVISION

*TM Monogram Industries, Inc.
**names furnished on request

TO HELP YOU BUILD AND MAINTAIN OUR NATION'S VITAL RAILWAYS.

- Crushed slag
- Sand and gravel
- Ready mixed concrete
- Crushed stone
- Industrial sand
- Bituminous concrete
- "Enslag Colmix" (a bituminous paving mixture laid cold)

PRODUCTS PRODUCED TO MEET YOUR ENGINEERING SPECIFICATIONS.
Fast, on-schedule deliveries and streamlined production from more than 130 strategically located plant facilities.
Call Joe Lynch

Vulcan Materials Company
ONE OFFICE PARK, BIRMINGHAM, ALABAMA 35223, TELEPHONE 205/879-0421

EXPERIENCED SPECIALISTS IN THE REPAIRS OF.... RAILROAD STRUCTURES

Turzillo CORPORATION ™

FOUNDATIONS, UNDERPINNING AND INVESTIGATIONS

AUGERCAST®* Piles — placed without vibration
- For new foundations and underpinning
- Retaining wall piles. Low headroom piles
- Tie-back anchoring system for excavations
- Tension piles and anchors

PRESSURE GROUTING
- BAGPIPE®* Groutainer™ inflatable forming system
- Soil stabilization for arresting settlement of structures
- FIRM-UP® chemical grouting for consolidating soils
- Consolidating masonry bridge abutments and piers

CONCRETE AND MASONRY STRUCTURAL REPAIRS
- Bridges, dams, power plants and dry docks
- Scour repairs
- Tunnel lining repairs
- Repairs to precast, concrete, wood and steel piles

PREPLACED AGGREGATE CONCRETE (PAC)
- Cofferdam seals
- Underwater repairs, piers and abutments
- High density concrete for shielding
- Concrete and masonry structural repairs
- Underwater concrete

ONE-SOURCE MARINE SERVICES
- Inspections above and below water
- Engineering reports of inspections
- Staff of experienced divers to perform corrective repairs
- Submit budget or firm quotes
- Complete the work based on findings or at the direction of Owner's engineering department or consultant

* Covered by U. S. and Canadian Patents

P. O. BOX 155 • BRECKSVILLE, OHIO 44141 • TELEPHONE 216/659-3141
ATLANTA • BALTIMORE • CHICAGO • DETROIT • FT. LAUDERDALE • HOUSTON • JACKSONVILLE
MINNEAPOLIS • OMAHA • SEATTLE • TORONTO • TULSA
AFFILIATES: LEE TURZILLO CONTRACTING CO. • AUGERCAST PILE & FOUNDATION COMPANY
TURZILLO CONTRACTING LTD.

Two for the road ...and then some!

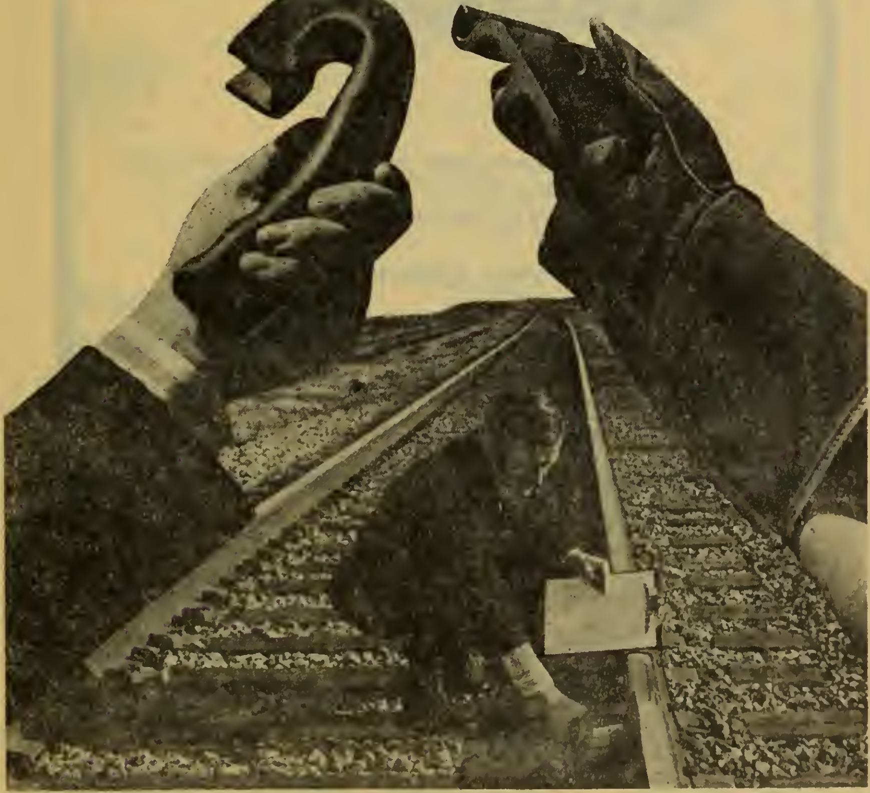
Channeloc®
Massive, unique channel shape provides tremendous gripping power. Its great tensile strength adds years to service life . . . and saves replacement costs. Channeloc is applied easily and quickly with minimum ballast disturbance . . . and can be reapplied.

Cliploc® . . . designed, tested and proven for modern concrete tie installations. Choose from standard Cliploc or insulated Cliploc with permanent fiberglass-reinforced epoxy for 100% insulation.

Cliploc®

To assure continued quality control, True Temper maintains a Field Service Department. These field engineers spot-check rail anchor applications and return at specified intervals to check in-service durability.

TRUE TEMPER®
RAILWAY APPLIANCE DIVISION
A MEMBER COMPANY OF ALLEGHENY LUDLUM INDUSTRIES



Channeloc is protected by U.S. Patent Numbers 3,102,690 — 3,118,327 — 3,159,198. Cliploc is protected by U S. Patent Number 3,477,642.

KERITE CABLE

For dependability in actual use, no other cable matches Kerite. We believe you will be impressed by the evidence.

MEMBER RPI

THE KERITE COMPANY

PRINCIPAL OFFICES: Boston; Chicago; New York; Philadelphia; San Francisco; and Seymour, Connecticut · Sales Representation throughout the United States. A subsidiary of Harvey Hubbell Incorporated.

DAYS KERITE

it's the **KERITE** *insulation that makes the difference*

You'll save time, trouble and money when you switch to PORTEC Track Equipment the leader in quality and delivery.

Ask your Portec man for details.
Or contact:

MEMBER
RPI
RAILWAY PROGRESS INSTITUTE

PORTEC inc.
300 Windsor Drive
Oak Brook, Illinois 60521
Telephone: 312/325-6300

In Canada: **PORTEC, LTD.**
500 Dominion Square Bldg.
Montreal, Quebec H3B1G4
Telephone: 514/866-9368

Portec Mark III Pak® Plastic Renewal Kits

Up to 10 times the service life of fibre insulation.

Portec-Bond® Insulated Rail Joints

Up to 980,000 lb. adhesive shear strength, with half the labor required to install other joints.

Portec Fair Rail Anchors

More sq. in. of tie bearing area than any other anchor. Installs faster, too.

Portec Poly-Insulated® Rail Joints

Rugged, urethane-encapsulated, heat-treated steel cores. Unexcelled performance.

Portec Portable Model 75 Heater

Faster, lower-cost curing of any bonded joint... with instant temperature read-out gauge. Unique!

Portec Rail & Flange Lubricators

Reduce costly friction wear. Overwhelming favorite of American Railroads.

Make tracks with the leader PORTEC inc.

TELEWELD
INC.

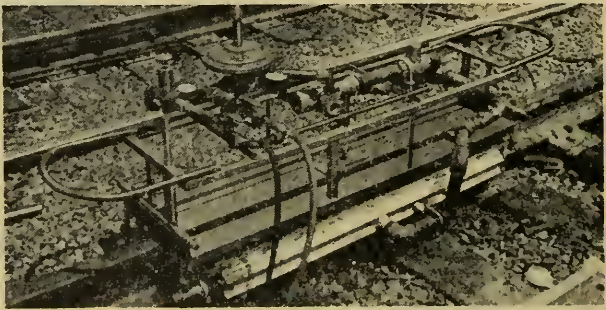
Rail Maintenance Service

Rail End Welding
Rail End Hardening
CWR Joint Normalizing
Frog and Switch Welding

MEMBER
RPI
RAILWAY
PROGRESS
INSTITUTE

Rail Maintenance Equipment

Custom Manufacturing and Fabrication
Joint Bar Shims
Rail Anchor Shims
Rail End and Frog and Switch
Welding and Grinding Machines
CWR Heating and Cooling Equipment
Rail Flaw Testing Equipment
Telebrineller Portable Hardness Tester



Infra-Red Heater for Curing Adhesive Bonded Rail Joints

TELEWELD INC., 416 NORTH PARK ST., STREATOR, ILL. 61364
Write for details of the TELEWELD process for restoring rail ends.

PART 2

REPORTS OF COMMITTEES

Note: Discussion on subcommittee reports herein closes on January 20, 1975.

Report of Committee 9—Highways

C. A. Christensen,
Chairman
L. T. Cerny,
Vice Chairman
G. U. Mentjes, *Secretary*

J. E. Spangler
J. R. Summers
P. A. Shuster
H. L. Michael
T. H. Kruttschnitt, Jr.
A. O. Kruse
T. P. Cunningham
C. W. Smith
R. E. Skinner
J. L. Whitmeyer
P. J. McCue
W. W. Allen
H. J. Barnes
J. M. Bates
J. P. Bolling
W. B. Calder
A. L. Carpenter
J. W. Cruikshank
F. Daugherty
R. A. Downey
L. L. George
R. V. Gilbert
H. D. Hahn
C. I. Hartsell

Wm. J. Hedley (E)
D. P. Insana
P. G. Jefferis, Jr.
M. D. Kenyon
R. V. Loftus
R. F. MacDonald
R. A. Mather
J. C. Miller
H. G. Morgan (E)
R. H. Patterson
W. C. Pinschmidt (E)
J. E. Reynolds
H. A. Richards
F. E. Rosencranz
P. L. Sehnert
C. Shoemaker
R. F. Spars
M. R. Sproles
D. Veitch
W. E. Webster
H. J. Wilkins
H. L. Woltman
C. H. Worboys
K. E. Wyckoff
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Recommended Manual revisions submitted for adoption are printed in Part 1 of this Bulletin.

1. Grade crossing inventory and accident report forms, records and practices. Information is being gathered and the committee expects to develop recommendations for new report forms and signs in the coming year.

2. Merits and economics of types of grade crossing surfaces.
No report for past year's activity. The committee worked on three drawings of highway-railway crossings to be included in the Manual.

3. Summary reporting of significant publications on grade crossing safety.
Summarized reports furnished as information .... page 250

4. Evaluation of developments in passive and non-train-actuated grade crossing warnings.
No report for past year's activity.

5. Study of motor vehicle codes and drivers' licensing practices.
No report for past year's activity.

6. Air rights for highways over railroad property.
No report for past year's activity. Highway Research Board's Report No. 142 has recently been released and it will be reviewed by the committee.

7. Evaluation of developments in train-actuated grade crossing warnings, collaborating as necessary or desirable with Communication and Signal Section, AAR.
   Progress report submitted as information .... page 256
8. Investigate uses and types of rumble strips and their adaptability for approaches to highway-railway grade crossings.
   No report for past year's activity.
9. Study of public pedestrian crossings.
   No report for past year's activity.
10. Summary reporting of administration of state crossing safety programs.
   A new subject. No report for past year's activity.

THE COMMITTEE ON HIGHWAYS,
C. A. CHRISTENSEN, *Chairman.*

Report on Assignment 3

Summary Reporting of Significant Publications on Grade Crossing Safety

H. L. MICHAEL *(chairman, subcommittee),* L. L. GEORGE *(vice chairman, subcommittee),* W. W. ALLEN, J. P. BOLLING, A. L. CARPENTER, L. T. CERNY, C. A. CHRISTENSEN, M. D. KENYON, A. O. KRUSE, R. V. LOFTUS, R. A. MATHER, R. H. PATTERSON, H. A. RICHARDS, R. E. SKINNER, C. W. SMITH, J. R. SUMMERS, DAVID VEITCH, J. L. WHITMEYER, H. J. WILKINS, H. L. WOLTMAN.

INTRODUCTION

The subcommittee assignment continues to be the reporting in summary format of significant publications or developments in grade crossing safety. This year 11 publications and progress on several significant research projects in grade crossing protection are reported.

"HUMAN FACTOR COUNTERMEASURES TO IMPROVE HIGHWAY-RAILWAY INTERSECTION SAFETY," BIOTECHNOLOGY, INC., PREPARED FOR U. S. DEPARTMENT OF TRANSPORTATION, WASHINGTON, D. C., JULY 1973 (NTIS, PB-223-416)

A field demonstration study in support of the evaluation of alternative railway-highway grade crossing accident countermeasures was conducted.

Guidelines were provided for the development of countermeasure concepts, the selection of candidate countermeasures, countermeasure evaluation methods, and experimental design procedures.

Investigations of the causative factors of accidents showed that maintenance of protective warning devices, driver attention and driver expectancy were precipitating and predisposing factors in accidents.

An appraisal of inherent driver safety potential was made which included driver education and licensing, safety programs and law enforcement, attitude and habit components of railway-highway safety and psycho-physiological capabilities and limitations.

A broad base of data was obtained in a demonstration field study conducted in five states. Information was obtained on driver behavior, knowledge and attitude. Three data collection procedures were used: The Traffic Evaluator System, time-lapse photography, and motorist response to questionnaires. An extensive analysis was performed on the data obtained to suggest countermeasure concepts and to determine target populations for effective countermeasure intervention.

Measures of driver performance were developed which were shown to be sensitive to countermeasure intervention. Under restricted conditions, driver looking behavior, crossing speed and speed decrease were shown to be sufficient and valid measures of performance to evaluate the effectiveness of a countermeasures intervention.

"GRADE CROSSING PROTECTION IN HIGH-SPEED, HIGH-DENSITY, PASSENGER-SERVICE RAIL CORRIDORS," TRANSPORTATION SYSTEMS CENTER, PREPARED FOR U. S. DEPARTMENT OF TRANSPORTATION, WASHINGTON, D. C., SEPTEMBER 1973 (NTIS PB-223-902)

This report is a preliminary examination of special aspects of grade crossing protection for operation of high-speed passenger trains in rail corridors for which complete grade separation is not possible. Overall system needs and constraints are indicated, and their implications examined. Application of conventional and improved hardware is considered, with special attention to activation criteria, appropriate motorist warning devices, stalled-vehicle indicators, and train-mounted components. Non-technical aspects of the problem are also discussed, and areas for which future research efforts may be appropriate are identified.

"INFLUENCING FACTORS FOR RAIL-HIGHWAY GRADE CROSSING ACCIDENTS IN FLORIDA," THE FLORIDA STATE UNIVERSITY, PREPARED FOR FLORIDA DEPARTMENT OF TRANSPORTATION, STATE OF FLORIDA, 1974

Using data from grade crossings in Florida, a model was developed for the prediction of expected accidents at highway-railway grade crossings. The model selected contains eight independent variables which resulted from evaluation of 39 possible variables. The variables found to be significant were daily vehicular traffic, maximum train speed, trains per day, and number of highway lanes. The remaining four variables involve the nature of the warning devices at the crossing.

The model selected is a statistical reasonable model and also reasonable from the point of view of application in that the variables are among those considered likely to be useful. The model is disappointing in that it explains only 43% of the total variation in numbers of accidents. This, however, is better than that reported by Voorhees. In order to improve the model it is necessary that the accuracy of the accident data be improved and that driver characteristics be included in the model.

The authors note that no model will ever be able to explain all the variation in accident statistics. Some crossings will have more or less accidents than predicted. However, the authors continue, an accident rate prediction model offers more benefit for an upgrading program than one which is based on the greatest number of accidents in recent years.

"AN EVALUATION OF FIVE RAILROAD ENGINE-ALERTING AND WARNING-LIGHT SYSTEMS," NAVAL AMMUNITION DEPOT, CRANE, INDIANA, FEBRUARY 1974 (NTIS, AD-779-878)

The purpose of this project was to conduct a limited examination of five proposed supplemental locomotive lighting systems which were designed both to increase locomotive conspicuousness and increase the perceptual accuracy of an oncoming locomotive's speed and distance. The five light systems were compared to a standard locomotive headlight. Three experiments were conducted. Comments concerning the light systems were obtained from the train crew which piloted the locomotive during the experiments. These comments are reported as well as information regarding the maintenance records of the light systems.

In all three experiments a NAD Crane locomotive specially painted in a high visibility pattern was used to display the light systems. The following light systems were investigated:

a. *Bicolor Radial Beacon.* In operation, the beacon generates a bright display of alternating red and white rays through a full 360 degrees. If either, or both, the locomotive or observer is moving, the observer will pass alternately through red and white rays, providing the illusion that the light is flashing red and white.

b. *Fast Strobes.* Two strobe tubes fired simultaneously at a rate of 2.5 flashes per second.

c. *Slow Strobes.* Two strobe tubes were designed to operate as white alternately flashing lights during the day and red simultaneous lights by night. The lights flashed at a rate of one flash per second.

d. *Clearance Lights.* Clusters of amber-lensed truck clearance lights were mounted at the four corners of the cab front. A fifth cluster was centered between the two lower clusters. Other clusters were mounted on the left side of the cab. (The right side was not visible to the subjects).

e. *Fluorescent Strobe Panels.* Two 2- x 2-ft panels containing 40 w fluorescent tubes and a Xenon flash tube (2 fps) in one panel were mounted on the left side of the locomotive.

f. *Standard Headlight.* The headlight was always operated in the low beam setting.

Tests were made at 10, 20, and 30 mph under daylight and night conditions. Some advantage was found for the strobe systems and for the clearance lights as compared to the usual fixed locomotive headlight. Recommendations for further research were made.

"ANALYSIS OF DRIVER REACTION TO WARNING DEVICES AT A HIGH-ACCIDENT RURAL GRADE CROSSING," JOINT HIGHWAY RESEARCH PROJECT, PURDUE UNIVERSITY, AUGUST 1974

The objectives of this research were to analyze the effect on motorists of improving the warning devices at a high-accident, rural grade crossing, from 8-inch flashers to automatic gates and 12-inch flashers activated by Marquardt speed predictor and having additional strobe lights; to evaluate suitable parameters to make the analysis; to study accident history and site conditions and relate these to motorist reaction to the system—before and after; and to evaluate the data collection system itself.

Spot speeds were taken at eight points on each approach to obtain an approach speed profile for various groups under various conditions after the signal system was improved. These were compared to similar data taken before system improvement.

It was shown that an activated gate arm can be as effective in slowing the average approaching vehicle as a train across the road. Train and signal conspicuity were a problem and contributed to the poor accident record of older drivers. The strobe lights made the warning system more visible after activation.

Most drivers approach a grade crossing safely, and mean speed of various groups shows trends but is a relatively weak parameter to test effectiveness because it does not isolate the occasional, unsafe driver. Percent reduction of fastest cars, along with examining individual "fastest" cars, is a better parameter than mean speeds and decelerations to show improved effectiveness.

"The Effectiveness of Automatic Protection on Reducing Accident Frequency and Severity at Public Grade Crossings in California," California Public Utilities Commission, San Francisco, California, June 1973

This is another in the continuing series of reports by the California Public Utilities Commission on automatic devices installed at 1,552 public grade crossings in California between 1960 and 1970.

The results of this study further substantiate that automatic devices are tremendously effective in reducing accidents and casualties. The use of flashing light signals and automatic gates has reduced accidents at the studied crossings by 68.6% and casualties per accident by 42%.

Automatic devices are superior to other types of protection because of the visual and auditory impact they have on drivers.

Automatic gates are especially effective in preventing accidents and casualties at new crossings.

The effectiveness of automatic protection is dependent upon crossing location, and effectiveness after installation is dependent upon train volumes, the development in the area of the crossing and on the percentage of crossings protected by gates.

Automatic protection can reduce accidents by only so much. The final responsibility for preventing accidents must rest with the driver. Automatic devices will help prevent accidents caused by natural conditions, such as reduced sight distance or the general inability to see or perceive an approaching train; accidents caused by high traffic or rail volumes; accidents caused by trains operating on multiple tracks; and, in part, accidents caused by distractions and other road hazards. Automatic devices will not prevent accidents caused by complete driver inattention; excessive vehicular speed; violations of the law; or lack of driver judgment. Automatic devices are a tremendous preventative tool but they will only reach their potential when combined with a driver awareness of the hazards involved and the obligation a driver faces when approaching a rail-street crossing.

"Summary and Analysis, Railroad-Highway Grade Crossing Accidents," Utilities and Transportation Commission, Olympia, Washington, July 1974

This is the annual report on grade crossing accidents in the state of Washington. Considerable statistical data on 1973 accidents are included and compared to the

1972 data. The general characteristics of accidents in 1973 were found to be very similar to those of previous years.

This annual report together with those of earlier years offers much data to those interested in further study of the grade crossing accident problem.

"ARIZONA CORPORATION COMMISSION GENERAL ORDER R-1 (AMENDED)," ARIZONA CORPORATION COMMISSION, OCTOBER 1973

Rules and regulations which apply to the construction, reconstruction, improvement, and maintenance of all public railroad-highway grade crossings within the State of Arizona are contained in the report. Standards included pertain to:

1. Railroad crossbucks
2. Automatically controlled crossing signals
3. Flashing light signals
4. Bell warning signals
5. Automatic gate arm signals
6. Maintenance
7. Whistle posts

Additional requirements are also set forth. Most of the amendments made were to bring the standards into consistency with the provisions of the Arizona Manual on Uniform Traffic Control Devices.

"FHWA NOTICE: ELIMINATION OF HAZARDS OF RAILROAD-HIGHWAY GRADE CROSSINGS—USE OF AUTOMATIC GATES," FEDERAL HIGHWAY ADMINISTRATION, WASHINGTON, D. C., MARCH 1973

The purpose of this notice is to encourage increased use of automatic gates at railroad-highway grade crossings. It is an amplification of FHWA's previous position on the use of gates.

Experience records indicate that automatic gates, with flashing light signals as part of the installation, generally provide more effective protection than flashing lights alone. The addition of gates to flashing light signals can be expected to reduce the probability of an accident by two-thirds or more.

Automatic gates appear to provide the best return on the safety investment, particularly at crossings where traffic is heavy and other conditions favor their use. Special consideration should be given to using gates at crossings with any of the following characteristics:

1. High vehicle and train traffic volumes
2. High train speed
3. High approach vehicle speed
4. Moderately high combination of volume and speed
5. Usage by school buses and/or vehicles transporting hazardous materials
6. Other high hazard characteristics, such as continuing accident occurences even though active protection devices are in place
7. Crossings used by through trains where switching operations take place in proximity to the crossing.

"THE FEDERAL HIGHWAY ACT OF 1973 AS IT APPLIES TO RAILWAY-HIGHWAY CROSSING SAFETY PROJECTS," SOUTHERN PACIFIC TRANSPORTATION COMPANY AND ST. LOUIS SOUTHWESTERN RAILWAY COMPANY, OCTOBER 1973

This handy, useful booklet reviews those portions of the 1973 Federal Highway Act which are applicable to railway-highway crossing safety projects.

Provisions of the 1973 Highway Act are significant and could be far-reaching in its program to eliminate hazards at railway-highway crossings. The Act contains authorizations for appropriations which cannot be used for any projects other than the elimination of hazards at grade crossings on the Federal-aid Systems, and the Safer Roads Demonstration Program authorizes appropriations for railway-highway safety and other types of highway improvements on roads which are not on any Federal-aid system.

The booklet briefly discusses each of the significant (to grade crossings) sections of the Act and in clear terms reviews requirements, funds available, and indicates actions by railroads and local governmental units which are necessary to implement the provisions of the Act.

"NEW PRIORITY FOR GRADE CROSSING SAFETY," ASSOCIATION OF AMERICAN RAILROADS, WASHINGTON, D. C., 1973

Another handy booklet which explains in a clear and concise manner how federal funds can be obtained for grade crossing improvements. The 1973 Federal Highway Act as pertains to grade crossings is reviewed and prompt action by interested agencies is urged. Examples of types of projects which may be included are listed as is availability of funding.

The booklet will be of value to state and local governments, railroads and others in promotion of grade crossing projects and in guiding development of such programs.

RESEARCH IN PROGRESS

Numerous research projects in the area of railway-highway grade crossings continue in many areas of the country. Many of these are sponsored by the Federal Highway Administration and/or the Federal Railroad Administration through state highway departments, at the Transportation Systems Center or by contract with consulting firms. Projects in progress include:

1. New passive devices (The Pooled Fund Project)
2. Grade crossing surfaces (Texas)
3. New passive devices (New Jersey)
4. Accident potential study
5. In-vehicle warning systems
6. DOT-AAR crossing inventory
7. Train conspicuity
8. Warning device equipment standardization
9. Innovative action warning concepts
10. Low-cost crossing barrier device
11. Locomotive conspicuity
12. Guidelines for crossing warning installations
13. Improved flashing lights
14. Motion detection devices
15. Impact attenuation devices on locomotives

More details on the above items may be available from the Federal Railroad Administration and/or the Federal Highway Administration.

The Committee on Highway-Railroad Grade Crossings of the Transportation Research Board, Washington, D. C., has also initiated through Highway Research Circulars periodic reporting of railroad-highway grade crossing research activity. The first of these Circulars (Number 157) was issued in July 1974. Items reported include annotated bibliographic information on recent research publications resulting from grade crossing research and notes on research in progress.

CONCLUSION

Of special significance to railroad-highway grade crossing safety was the publication during the year of AAR Bulletin No. 7, Railroad-Highway Grade Crossing Protection, Recommended Practices. This updated Bulletin is recognized as an important statement of recommended practices in the field of railroad-highway grade crossing safety.

Research and development in the grade crossing safety area are currently very active, and a number of significant publications in this area are scheduled for each of the next few years. As a consequence, it is recommended that the assignment of this subcommittee be continued as currently stated.

Report on Assignment 7

Evaluation of Developments in Train-Actuated Grade Crossing Warnings

C. W. Smith *(chairman, subcommittee),* H. J. Barnes, J. P. Bolling, L. T. Cerny, C. A. Christensen, T. P. Cunningham, L. L. George, C. I. Hartsell, D. P. Insana, P. G. Jefferis, Jr., R. A. Mather, H. L. Michael, J. E. Reynolds, H. A. Richards, Clifford Shoemaker, R. E. Skinner, David Veitch, W. E. Webster, Jr., J. L. Whitmyer, H. L. Woltman.

Last year your committee reported that information was being assembled relative to this assignment, with emphasis being directed to the high-speed rail corridor between Washington and New York.

This report is submitted as information, and pertains to the grade crossings located along this corridor in the State of Maryland.

Subsequent reports will be submitted relative to the subject for the State of Delaware and the Commonwealth of Pennsylvania.

Maryland

There are 15 grade crossings along the high-speed rail corridor in Maryland, located, by counties, as follows:

Cecil County
    Iron Hill Road
    Elk Neck Road
    Mechanic's Valley Road
    Caroline Lane

Harford County
    Md. 132 (Belair Avenue)
    Michaelsville Road
    Chelsea Road

Baltimore County
    Ebenezer Road
    Patapsco Avenue
    Knecht Avenue

Anne Arundel County
    Stony Run Road

Prince Georges County
    Hillmeade Road
    Jericho Park Road
    Md. 193 (Glenn Dale Road)
    Seabrook Road

Previous warning devices at all crossings consisted of automatic flashing light signals and gates.

The warning added at each of the 15 crossings was a 48- x 48-inch warning sign, with the message HIGH SPEED TRAIN, erected 100 ft from the crossing on each approach.

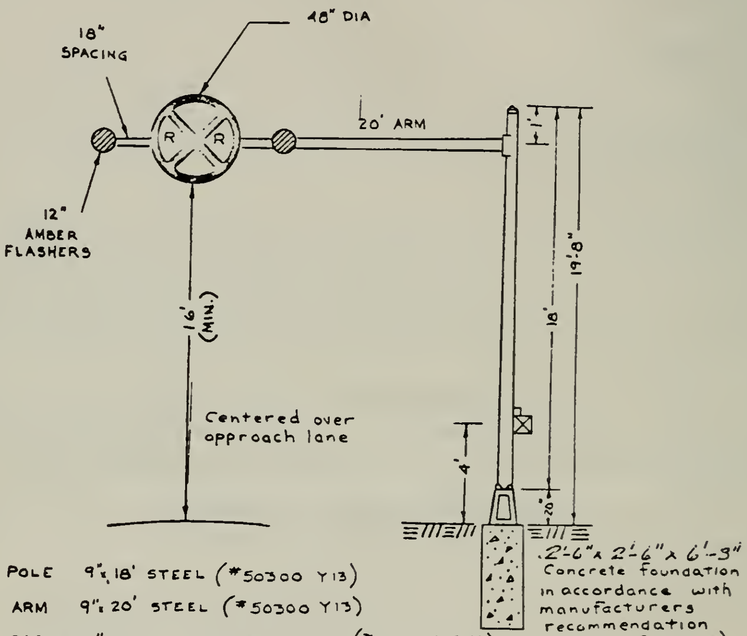
In addition, cantilevered standard railroad advance warning signs with amber flashing lights activated by and operating in conjunction with the existing flashing light signals, were installed 300 ft from the crossing on each approach (see drawing on next page).

Accident records are not available, but it is the opinion of the Maryland authorities that the additional warning devices have been beneficial.

TYPE I

OVERHEAD ADVANCE FLASHER

(FOR HIGH SPEED TRAIN CROSSING)



POLE 9" x 18' STEEL (#50300 Y13)

ARM 9" x 20' STEEL (#50300 Y13)

BASE 20" HIGH FRANGIBLE ALUMINUM (#1Y-A2875Y2)

Note: Where appropriate, a Type II installation with a non-frangible flush with ground base was constructed using 9" X 20' steel pole to replace the Type I pole and base shown above.

REVISIONS

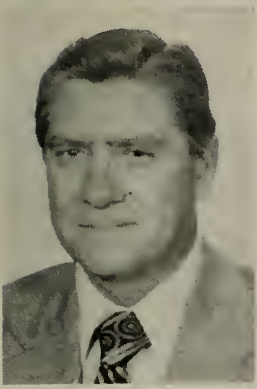
Maryland State Roads Commission
Bureau of Traffic

DW

LOCATION ____

DATE Oct 25, 1968 SCALE 1" = 5'0"

Report of Committee 11—Engineering Records and Property Accounting



R. D. Igou, *Chairman*

L. F. Grabowski,
Vice Chairman

G. R. Gallagher,
Secretary

M. F. McCorcle
P. G. McDermott
W. C. Kanan
R. L. Ealy
A. P. Hammond, Jr.
C. J. McDonald
C. E. Bynane
J. G. Kirchen
F. B. Baldwin (E)
P. J. Beyer, Jr.
H. C. Boley*
J. M. Bourne
W. F. Burt
R. H. Campbell
P. L. Conway, Jr.
J. R. Cressman
C. R. Dolan
W. V. Eller
L. D. Farrar
J. R. Geary
C. C. Haire (E)
M. J. Hebert
P. J. Hendricksen
E. H. Hofmann
P. R. Holmes
J. J. Hoolahan
L. W. Howard
N. J. Hull, Jr.
G. F. Ingraham
J. W. Kelly
H. C. Lippy
W. F. Liszewski
R. W. Lively
J. G. Maher
J. L. Manthey
D. C. Maris
J. C. McKeague
D. M. Meyer
S. Miller, Jr.
G. L. Muchow
B. F. Nauert
P. R. Neff
J. J. O'Hara
C. F. Olson
A. H. Patterson
H. L. Restall (E)
J. M. Randles
P. W. Roberts
R. S. Shaw, Jr.
E. E. Strickland
J. B. Styles
T. A. Valacak
H. R. Williams
Committee

---

* Died February 1, 1974.
(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association

Your committee reports on the following subjects:

B. Revision of Manual.
Progress report, presented as information .... page 260

2. Bibliography.
Progress report, presented as information .... page 261

3. Office and drafting practices.
Final report on status of AFE projects, presented as information .... page 262

4. Special studies.
No report. Methods for preparing standard form AFE estimates by mechanized process under study.

5. Application of data processing.
No report. Methods of allocating recorded cost of reported units under study.

6. Valuation and depreciation.
Progress report, presented as information .... page 264

7. Revision and interpretation of ICC accounting classifications.
Progress report, presented as information .... page 265

The Committee on Engineering Records and Property Accounting,
R. D. Igou, *Chairman.*

Harold C. Boley
1907-1974

Harold C. Boley, valuation engineer system of the Atchison, Topeka & Santa Fe Railway, with headquarters at Topeka, Kan., died February 1, 1974, at the age of 66. He was a licensed professional engineer and had been employed by the Santa Fe for 27 years.

Mr. Boley was born at Topeka on July 21, 1907, and received his higher education at Kansas State University at Manhattan. He began his railroad career for the Santa Fe in 1946 as a computer in the valuation engineer's office for the Eastern Lines at Topeka. He was promoted to assistant engineer in 1958 and to valuation engineer three years later.

Mr. Boley served in the Army and Army Reserves 32 years and held the rank of colonel when he retired. He was a veteran of World War II, having served with the field artillery. He later served as commandant of the 5905th Army Reserve School in Topeka.

Mr. Boley was a member of the Kansas Engineering Society and the Topeka Engineers Club. He joined AREA in 1957 and was co-chairman of subcommittee 5 of Committee 11 at the time of his death. Harold had a constant interest in Committee work, and was always a willing participant in discussions and subcommittee assignments. His passing will be both a personal and professional loss to all the members of Committee 11.

He is survived by his widow, Mrs. Alice Boley and a son, Roy Boley, both at Topeka; a daughter, Mrs. Marilyn Robyak, Centreville, Va.; a stepson, Major Mike Blaisdell, Norfolk, Va.; two stepdaughters, Mrs. Janice Bowen, Pittsburg, Kan., and Mrs. Martha Derda, Schaumburg, Ill.; and 12 grandchildren.

Report on Assignment B

Revision of Manual

M. F. McCorcle *(chairman, subcommittee)*, P. J. Beyer, Jr., L. D. Farrar, M. J. Hebert, E. H. Hofmann, J. J. Hoolahan, John McKeague, G. L. Muchow, R. S. Shaw, Jr., H. R. Williams.

A report on Status of AFE Projects was prepared by Subcommittee 3 and published in Part 1 of this Bulletin, with the recommendation that it be adopted and published in the Manual.

Report on Assignment 2

Bibliography

P. G. McDermott *(chairman, subcommittee)*, P. J. Beyer, Jr., J. R. Cressman, C. R. Dolan, L. D. Farrar, A. P. Hammond, R. D. Igou, J. L. Manthey, J. J. O'Hara, E. E. Strickland, T. A. Valacak.

Your committee submits the following report of progress, presenting additional references with annotations.

Office Procedure

Modern Office Procedures, December 1973, "Pointers on Buying Software."

Smart software shopping techniques have become a must for office executives.

Reprographics, December 1973, pages 6–11. "Reprographics '74."

Four prominent spokesmen in the drafting and engineering reprographics industry offer a hard-hitting analysis of what to expect in 1974.

Reprographics, April 1974, pages 8 & 11. "Preparing Drawings for Microfilming Calls for That 'Extra-special' Care."

A negative can never be better than the drawing.

Reprographics, April 1974, pages 12 & 14. "Case Study: How to Use Flexible Overlays."

One fundamental element in the system is that a draftsman should never have to draw something twice. A program of flexible overlays is the answer.

Business Graphics, May 1974, page 18. "Computer Handling of Engineering Drawings on Microfilm."

New IBM system promises high-volume, selective machine duplication and distribution of aperture cards.

Business Graphics, June 1974, pages 40–42. "Preparing Damaged Records for Microfilming."

One of the least publicized applications for microfilm is its use in reclamation of water-damaged records, as well as those that have been mildewed, covered with mud, etc.

Accounting

The American Appraisal Company, Inc. Clients' Service Bulletin, April 1974. "Current Value Accounting."

What is the validity of using current values? Rather than offering a panacea, it is an alternative to the traditional system which fails to consider present economic conditions.

The Practical Accountant, March–April 1974. "A Basic Approach to Inventory Valuation: A Bird's Eye View."

This article discusses the six basic precepts in inventory valuation and shows how they interrelate.

GENERAL

Reprographics, April 1974, pages 1, 16 & 18. "Improving Your Manpower Mileage."

There is no shortage of engineering manpower but a shortage of managers at all management levels who know how to effectively utilize the manpower they have. This article describes a method of organizing for maximum utilization.

Report on Assignment 3

Office and Drafting Practices

W. C. KANAN *(chairman, subcommittee),* P. J. BEYER, J. M. BOURNE, R. H. CAMPBELL, P. J. HENDRICKSEN, J. J. HOOLAHAN, J. W. KELLY, J. G. KIRCHEN, J. L. MANTHEY, M. F. MCCORCLE, G. L. MUCHOW.

STATUS OF AFE PROJECTS

Your committee submits, as information, the results of answers to a questionnaire pertaining to its report on Status of AFE Projects.

In order to establish control and report on the progress toward physical completion of Authorities for Expenditures, most railroads prepare a periodic report commonly referred to as the Status of AFE Projects.

The conclusions reflected or procedures referred to herein cover data contributed by 17 carriers.

All 17 carriers reported their railroad prepares a report on the Status of AFE Projects.

An AFE Status Report is prepared by the department having the AFE activity as follows:

1. Operations
2. Engineering
3. Mechanical
4. Communications—Signalling
5. Real Estate

Four carriers reported the Status Report was prepared in the above departments and consolidated into a system report by Valuation Department and three reported it was consolidated by the Accounting Department.

Fifteen carriers reported their Status Report is prepared monthly and two reported it prepared every other month with a wire report of completed projects monthly.

Twelve carriers indicated their report is assembled by operating divisions. One carrier indicated its report is assembled by subject categories, i.e., buildings, bridges, etc.

Sixteen carriers reported that Operations, Engineering, Mechanical, Communications Departments submit separate Status Reports; one reported it did not.

7 carriers indicated they did not assemble a System Summary.

3 carriers indicated a System Summary was prepared by Valuation.

3 carriers indicated a System Summary was prepared by Accounting.

3 carriers indicated a System Summary was prepared by Engineering.

1 carrier indicated a System Summary was prepared by Operations-Management.

All 17 carriers reported items are added to the Status Report as soon as authority is granted or advance AFE number is issued.

Seven carriers indicate their Status Report reflects both percent of appropriation of dollars expended, as well as percent of physical completion.

Ten carriers indicate their Status Report reflects percent of physical completion only.

Depending upon the uses made by the various carriers as management information or control tool, the AFE Status Report is generally given wide circulation to all interested departments within the industry as follows:

Executive Department
Accounting Department, including AFE or Property Accounting
Operations Department
Engineering Department, including Signal-Communications & Valuation
Mechanical Department
Tax Department, including Income and Ad valorum
Finance Department
Real Estate Department

What purpose does Status Report serve to the various users?

The carriers reply to this question reveals that the Status Report is a useful and important report. A summary of various uses or functions is as follows:

1. Accounting adjustments on large betterment projects on the basis of percent of completion.
2. As a control against overexpenditures.
3. As management information to management control department.
4. Provides source of data for reporting overexpended authorities.
5. Used to forecast cash requirements by updating A & B Budget quarterly.
6. Used for progressive billing purposes on a percent complete basis.
7. Used by Accounting for a check on material and labor reporting.
8. Used by management as information on start, progress and completion of projects.
9. Used for budget analysis.
10. Used by Engineering for control on budget forecasting.
11. Triggers when to bill on 100 percent complete projects, Federal Aid, etc.
12. Departments affected select information from reports on as needed basis.
13. Can be tied into Responsibility Reporting System.

The carriers indicated that the Status Report is used in their Valuation or record keeping processes in the following manner:

1. Prepare monthly status of completions on projects 100 percent complete.
2. Prepare check list on completed projects for requesting Field Completion Report as built or as retired data.
3. Beginning and completion dates for Roadway Completion Reports.
4. Used for "in service" or "out of service" dates for depreciation purposes.
5. Used for annual "carry over" statement.
6. Used for estimates of expenditures and retirements on a periodic basis.

One carrier's Status Report was the most complete from valuation, accounting and record reporting standpoint. The Status Report is continued to 103% complete basis as follows:

100% Physically complete

101% As built drawings and detail due from field
102% As built received awaiting financial completion
103% Physically and financially complete reported one month and dropped.

Conclusion:

The report on Status of AFE Projects is a useful and important management tool. The format and general layout used by each carrier is similar insofar as data shown on the report. Some carriers' Status Reports are general in nature and others are quite sophisticated and appear to be computer generated.

Report on Assignment 6

Valuation and Depreciation

C. E. Bynane *(chairman, subcommittee)*, P. L. Conway, Jr., J. R. Cressman, W. V. Eller, G. R. Gallagher, L. F. Grabowski, M. J. Hebert, P. J. Hendricksen, E. H. Hofmann, P. R. Holmes, N. J. Hull, Jr., R. D. Igou, J. G. Maher, D. C. Marris, P. G. McDermott, C. J. McDonald, S. Miller, Jr., J. B. Styles, H. R. Williams.

(A) Current Developments in Connection with Regulatory Bodies and Courts

ICC Bureau of Accounts

During the fiscal year 1974 the Commission continued its five-year cyclical review of equipment depreciation and the Accounting and Valuation Board issued 40 railroad depreciation orders. Beginning in fiscal 1974, the depreciation analysis of all road property accounts for Class I railroads has been placed on a cyclical review program by the Commission and all Class I carriers were served during the period with a request to submit a road property study.

Entirely new concepts and formats have been utilized to develop a service life for road property and the analysis program now used by the Commission is designated as the simulated plant record program. A 14-page memorandum summarizing remarks and discussion at a June 26, 1972, meeting on Computerized Depreciation Analysis has been prepared by E. C. Hostettler, chief, Depreciation Branch, Bureau of Accounts, and discusses the simulated plant record program in some detail. Copies of the memorandum are available to interested parties upon request to the chairman of this subcommittee.

Road property depreciation analyses have been completed to date for 15 Class I carriers, and the results have been or will soon be communicated to the carriers for their review and acceptance or exception. It is understood that in general the results to date have been in line with expectations, and the anticipated large deficiency in past accrued depreciation has not developed. Some problems have developed in the program with respect to salvage, and this has resulted in the solicitation of additional salvage information from the carriers, particularly in Accounts 6—Bridges, Trestles and Culverts, Account 16—Station and Office Buildings; Account 26—Communication Systems; and Account 27—Signals and Interlockers.

Additionally, the ICC depreciation staff has directed a substantial number of inquiries to carriers concerning unusually large additions or retirements in some accounts. Close attention has been directed to areas where technical obsolescence (e.g. pole lines) may have occurred or will soon occur.

As information, the findings, with respect to the 15 carriers completed, have been used in the soon-to-be-released Interim Coordinator's report by Commissioner Hardin on Ex Parte 271, Net Investment—Railroad Rate Base and Rate of Return.

Internal Revenue Service

This subcommittee's report in AREA Bulletin 640, Proceedings Volume 74, pages 179–180, cited Revenue Procedure 71-25 wherein specifics for application of the then new ADR System were to be found. Revenue Procedure 72-10 has superseded 71-25.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

J. G. Kirchen *(chairman, subcommittee)*, J. M. Bourne, P. L. Conway, J. R. Geary, N. J. Hull, G. Ingraham, J. W. Kelly, W. Liszewski, J. G. Maher, D. C. Maris, P. McDermott, J. McKeague, D. M. Meyer, S. Miller, P. R. Neff, P. W. Roberts, T. Valacak.

A proposed Accounting Series Circular No. 130, Revised (Interpretations of the Uniform System of Accounts for Railroad Companies), which reflects substantive changes to the initial issue of September 1962, was circulated to chief accounting officers of railroad companies for their views and comments on August 28, 1974. Replies were requested to be submitted not later than October 31, 1974.

The proposed revised circular deletes, combines, revises and renumbers existing cases and adds ten new cases.

The ten new cases proposed cover the following subjects and accounts:

Case No.	*Description*	*Accounts Affected*
84	Rebuilt property.	Various
85	Computer-related costs.	16, 227, 266, 453
86	Premature retirement of depreciable property.	735
87	Replacement of wooden ties with concrete ties.	8, 10, Opr. Exp.
88	Sidetrack deposit refund agreements.	743, 782
89	Allocation of revenues under pooling agreements.	101, 143, 411
90	Property removed under salvage contract.	267, 270
91	Highway transportation expenses.	101, 318, 421, 422
92	Construction of track connections.	731, 732
93	Sale of land incident to retirement of track facilities.	519

ICC Circular No. 34178 (Sub. No. 2) with a service date of August 28, 1974, was issued regarding the accounting for income taxes—interperiod tax allocation (deferred taxes) to become effective retroactively to January 1, 1974.

This circular will correct the problem of having some transactions affecting the determination of net income for financial reporting purposes in one period but the computation of taxable income (and taxable payables) in a different period. In other words, the actual taxes payable for a period are not now always determined by the same revenue and expense items used at arriving at accounting income for the same period.

Report of Committee 14—Yards and Terminals

B. H. Price, *Chairman*

P. C. White,
Vice Chairman

G. H. Chabot, *Secretary*

R. F. Beck
H. L. Bishop
J. F. Chandler
A. L. Hunter
J. G. Skeen
P. E. Van Cleve
J. Zaenger

R. P. Ainslie
J. K. Aust
R. O. Balsters
H. R. Beckmann
A. E. Biermann
W. O. Boessneck (E)
R. O. Bradley
R. E. Bredberg
H. E. Buchanan
C. M. Burnette
H. B. Christianson
H. P. Clapp
M. K. Clark
D. V. Clayton
E. H. Cook
A. V. Dasburg
F. D. Day
P. J. DeIvernois, Jr.
P. P. Dunavant, Jr.
R. D. Dykman
V. H. Freygang
M. R. Gruber, Jr.
H. L. Haanes
J. N. Hagen
D. C. Hastings
I. M. Hawver
Wm. J. Hedley
L. J. Held
F. A. Hess (E)
C. F. Intlekofer
J. B. Kerby
A. S. Krefting (E)
W. L. Krestinski
C. J. Lapinski
J. A. LeMaire
S. J. Levy
E. T. Lucey
S. N. MacIsaac
J. C. Martin
A. Matthews, Jr.
H. J. McNally
R. E. Metzger
C. H. Mottier (E)
A. W. Niemeyer
F. J. Olsen
W. L. Patterson
L. J. Riekenberg
W. P. Rybinski
R. J. Samoska
W. D. Slater
C. E. Stoecker
E. Szaks
L. G. Tieman
J. N. Todd (E)
A. J. Trzeciak
H. Watts, Jr.
J. C. Weiser
D. W. Wessels
C. C. Yespelkis
J. R. Zebrowski
Committee

To the American Railway Engineering Association:

Your Committee reports on the following subjects:

B. Revision of Manual.

The committee has completed its review of the material as well as indexing to the decimal system. The committee is now reviewing the glossary as it pertains to its work.

1. Classification yards, collaborating as necessary or desirable with Committee 16.

   (a) Gradients for flat and saucer yards.

   No report.

   (b) Yard and terminal design criteria to decrease car detention.

   A report on this subject has been written, but has not been approved by the committee. This report will be issued in the coming year.

2. Bulk material handling systems, collaborating as necessary or desirable with Committees 6, 8, and 15.

   No report.

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

3. Terminal facilities for handling solid waste material from an ecology standpoint, collaborating as necessary or desirable with Committee 13.
   No report.
4. Design criteria for study of car rollability.
   A comprehensive report is herewith submitted as information, with the recommendation that additional studies and research on car rollability be considered .... page 265
5. Trends in intermodal facilities.
   No report.
6. New applications of computers to classification yards, collaborating as necessary or desirable with Committee 32.
   A report on this subject is herewith submitted as information, with the recommendation that the subject be discontinued .... page 272

THE COMMITTEE ON YARDS AND TERMINALS,
B. H. PRICE, *Chairman.*

Report on Assignment 4

Design Criteria for Study of Car Rollability

J. ZAENGER *(chairman, subcommittee)*, J. K. AUST, A. E. BIERMANN, R. F. BECK, R. O. BALSTERS, H. P. CLAPP, M. K. CLARK, D. V. CLAYTON, A. V. DASBURG, P. J. DEIVERNOIS, W. L. KRESTINSKI, C. J. LAPINSKI, J. A. LE MAIRE, S. J. LEVY, S. N. MAC ISAAC, J. G. MARTIN, A. W. NIEMEYER, W. L. PATTERSON, B. H. PRICE, R. J. SAMOSKA, HOWARD WATTS, JR., J. C. WEISER, P. C. WHITE, J. R. ZEBROWSKI.

Your committee submits the following report as information with the recommendation that future studies on car rollability be authorized.

The basic format, procedures, and data to be used in the design of hump or gravity classification yards are contained in Chapter 14 of the AREA Manual for Railroad Engineering. This approach to the design of hump yards is quite understandable and relatively easy to apply. However, while the theoretical fundamentals are still basically applicable, there has been an evolution in car characteristics, hump yard control equipment and systems, and railroad engineering practices. The car rollability data should be updated to become compatible with current equipment and operating practices.

PURPOSE

The purpose of this report is to establish the design criteria for a study of railroad car rollability. The results of that study should provide rational data which can be applied to the design of new yards, and the evaluation and redesign of existing yards. The ease with which the resulting car rollability data can be applied is an important aspect to such a study.

BACKGROUND

There are over 125 hump yards in North America. These yards vary in size from 6 to 84 tracks with bowl track lengths ranging from 800 to approximately

8,000 ft. Humping rates averaging 2 to 6 cars per minute are used for cars classified in these yards. In addition to the variety of yard sizes, geometry, and humping rates, the operations of many of these yards are further complicated by extreme climatic conditions that affect the rollability of cars.

The performance of these yards is determined by the distribution of the available energy in any car cut (single or multiple connection) as the cut rolls from the crest to its coupling point in the bowl. The total energy initially available is a function of the humping speed and the elevation of the cut's center of gravity at separation relative to the elevation of its center of gravity at the coupling point in the bowl. As the cut rolls toward the coupling point, energy can be lost by tangent and curved track rolling resistances, switch or turnout resistances, retarder action, track conditions, and weather factors.

Car rollability is a general term that should relate the various resistances to weights and types of individual cars or groups of cars. These resistances are usually expressed as gradients, fractional feet of velocity head, or in pounds per ton (of gross cut weight). Included in the resistances are such variables as journal or bearing losses, track and rail flexure, relative wind resistances, flange losses, car oscillations, wheel inertia (especially in empty cars), and energy dissipated in traversing curved track sections. Other factors which affect performance include retarder operations and abnormal car and track defects; these factors are important but should not be identified with car rollability.

In general, the design procedures referred to in Chapter 14 of the Manual accommodate the previously described resistance variables. The method for accommodating these variables, while relatively easy to apply, is quite subjective. There are not well-defined rules for applying the car rolling resistances for curved track and tangent track conditions; there are only ranges and maximum and minimum resistance values. As a result, it is rather difficult to quantify performance in comparison to cost variations that might result from adjusting the geometry and hardware required for different hump yard layouts.

Objectives

The principal objective of this report is to identify those car rollability factors associated with normally maintained cars rolling on normally maintained classification yard tracks. While no statistical guidelines are established in this report, the desire of the committee is that the car rollability data will be developed and provided on a statistical basis. This will enable those people applying these data to compare the statistical levels of yard performance to the costs and expenses associated with each performance level.

Approach

It is suggested that at least two hump yard facilities be used as sources of raw data and that at least one yard be subject to temperatures that extend well below zero. While it is not absolutely necessary, there would probably be economic advantages in incorporating the data measurement and collection with a digital computer associated with a new yard or one that is being modernized.

There are a number of items which will have an affect on the raw data collected during the rollability studies. These items would include: (1) humping speed;

(2) car identification/data; (3) track plan and profiles; (4) temperature; (5) wind velocity and direction; (6) track conditions, and (7) level of humidity (both atmospheric and on rails/wheels.

The resulting information should be in a format that is appropriate for use by those who would design hump yards or evaluate their performance. The list below describes a method of presentation; an actual study may determine that some of these items (e.g., tangent track rollability range) will not require the extent of the investigation indicated.

Car Characteristics

While most hump yards are used to classify a wide range of car types and under various conditions of loading, there are many single-purpose yards. Single-purpose hump yards would include such facilities as those handling only coal cars. For these reasons, car rollability data should be refined so that it can be segregated according to the following factors. Until data prove otherwise, car characteristics should be an integral part of the investigation of each type of rollability factor.

1. Car type
2. Car weight
    a. 20 tons to 160 tons
    b. increments of 5 tons
3. Coupled length
    a. 20 ft to 95 ft
    b. increments of 5 ft
4. Truck information
    a. type bearing
    b. number of axles
    c. axle-spacing
5. Wheel inertia factor
6. Standing or delay time from arrival at receiving yard to cresting at hump
    a. increments of 5 minutes for first 2 hours
    b. increments of 30 minutes for 2 through 12 hours
    c. increments of 1 hour for 12 through 24 hours

Tangent Track Rollability

This value should be developed on the basis of adjusting to a no-wind equivalent. Care should be taken to ascertain relative horizontal and vertical positions of the car center of gravity.

1. Distance range
    a. crest to 5,000 ft
    b. increments of 100 ft
2. Temperature range
    a. −20° F to +110° F
    b. maximum increments of 10° F
3. Velocity range
    a. 0 to 25 mph
    b. increments of 0.5 mph
4. Track conditions
    a. gage
    b. rail section
    c. level of maintenance description

Curved Track Rollability

The same no-wind equivalent and center-of-gravity factors recognized in tangent track rollability should be applied. Curved track resistance is currently applied as a value in addition to tangent track resistance; it should be determined if this procedure should be continued or replaced with a different method.

1. Curve data
    a. curve length to nearest 0.1 deg of central angle
    b. degree of curvature to nearest 0.1 deg
    c. superelevation data, if any, to nearest ⅛ inch
    d. type and method of lubrication, if any
    e. reversing tangent data, if any
    f. wheel straightening devices, if any
2. Temperature range—as in Tangent Track Rollability
3. Velocity range—as in Tangent Track Rollability
4. Track conditions—as in Tangent Track Rollability

Switch and Frog Resistance

Switch and frog resistance is currently applied as an independent value unrelated to car characteristics, tangent resistance, or curved track resistance. Wind and center-of-gravity effects should be eliminated from the developed data.

1. Temperature range—as in Tangent Track Rollability
2. Velocity range—as in Tangent Track Rollability
3. Track conditions—as in Tangent Track Rollability

General Comments

The center of gravity of any car and its relationship to the track geometry should be clearly recognized in both data measurement and interpretation. This will probably have its greatest effects in partially-loaded tank cars and cars with unbalanced loads.

If any measurement sections include retarders, open retarder drag effects should also be eliminated. These drag effects will primarily be a factor of the retarder type, retarder maintenance, and wheel thickness.

CONCLUSIONS

Car characteristics, control systems, and yard maintenance procedures have changed significantly in the 50 years since the basic design data for retarder-controlled hump yards were first developed. Railroad operations and evaluation techniques have become more sophisticated. The construction of a new hump yard or modernizing an existing facility are major investments.

In terms of throughput alone, a reliable measure of performance should be available to determine the effectiveness of the amounts of money invested in a hump yard. With reliable and flexible car rollability data, better decisions can be made with regard to variations in number and length of bowl tracks, control configurations, and humping rates. Better car rollability data should also enable improvements in control of coupling speeds on bowl tracks, thus reducing trimming requirements and damage to cars and lading.

Report on Assignment 6

Computer Applications to Classification Yards

A. L. Hunter *(chairman, subcommittee)*, A. E. Biermann, J. K. Aust, R. F. Beck, R. E. Bredberg, C. M. Burnette, A. V. Dasburg, F. D. Day, P. J. DeIvernois, H. L. Haanes, D. C. Hastings, L. J. Held, W. L. Krestinski, J. A. LeMaire, S. J. Levy, A. Matthews, W. L. Patterson, B. H. Price, J. M. Randles, H. Watts, Jr., J. C. Weiser, P. C. White, Jr., C. C. Yespelkis, J. Zaenger.

Your committee presents the following information pertaining to classification yards employing digital computers with the recommendation that the subject be discontinued.

1. *General*

The advent of the digital computer for use in process control systems took place in the late 50's and early 60's. The shrinking cost of storing a "bit" of information and the increased reliability of both computer hardware and software systems led to their rapid acceptance for use in process control. The railroad classification yard with its production line flows was a natural place to utilize this new tool. What the analog computer had accomplished for yard control purposes in the previous decade, the digital computer also accomplishes.

The digital computer performs the two basic process control functions of car routing and car control, and in addition it provides a management information function. It can perform an inventory function. It can keep a record of the order in which the cars are received on the classification tracks and display this information on read-out devices such as cathode ray tubes. The yard computer can also report to other computer systems which provide higher levels of management information.

2. *Tabulations*

This report provides the following tabulations for general information on yards employing digital computers:

a. Location and In-Service Date
b. Yard Configurations
c. Computer System Configuration
d. Computer Peripherals Utilized
e. Inventory Software

	DIGITAL COMPUTER YARDS TABULATION A LOCATION AND IN SERVICE DATE	GATEWAY (MOPAC)	EUGENE (SP)	BROSNAN (SOU)	BELLEVUE (N&W)	BAILEY (UP)	PERLMAN (P. C.)	NO. KANSAS CITY (BN)	ARGENTINE (AT&SF)	BUCKEYE (P. C.)	PASCO (BN)	ROANOKE (N&W)	CENTENNIAL (T&P)	BEOGRAD (YRR)	E. LOS ANGELES (UP)	CALDER (CN)	ALYTH (CP)	SHEFFIELD (SOU)	W. COLTON (SP)	INMAN (SOU)	LANG (D&TSL)	NORTHTOWN (BN)	STRAWBERRY (L&N)	RICE (SCL)	NORRIS (SOU)	BARSTOW (AT&SF)
1	EAST ST. LOUIS, MISSOURI	64																								
2	EUGENE, OREGON		66																							
3	MACON, GEORGIA			66																						
4	BELLEVUE, OHIO				67																					
5	NORTH PLATTE, NEBRASKA					67																				
6	SELKIRK, NEW YORK						68																			
7	KANSAS CITY, MISSOURI							69																		
8	ARGENTINE, KANSAS								69																	
9	COLUMBUS, OHIO									70																
10	PASCO, WASHINGTON										71															
11	ROANOKE, VIRGINIA											71														
12	FORT WORTH, TEXAS												71													
13	BEOGRAD, YUGOSLAVIA													71												
14	EAST LOS ANGELES, CALIFORNIA														71											
15	EDMONTON, ALBERTA, CANADA															72										
16	CALGARY, ALBERTA, CANADA																72									
17	SHEFFIELD, ALABAMA																	73								
18	COLTON, CALIFORNIA (NEAR LA)																		73							
19	ATLANTA, GEORGIA																			73						
20	TOLEDO, OHIO																				74					
21	FRIDLEY, MINNESOTA																					76				
22	LOUISVILLE, KENTUCKY																						76			
23	WAYCROSS, GEORGIA																							76		
24	BIRMINGHAM, ALABAMA																								76	
25	BARSTOW, CALIFORNIA																									76

DIGITAL
COMPUTER
YARDS

TABULATION B

YARD CONFIGURATIONS

		GATEWAY (MOPAC)	EUGENE (SP)	BROSNAN (SOU)	BELLEVUE (N&W)	BAILEY (UP)	PERLMAN (P. C.)	NO. KANSAS CITY (BN)	ARGENTINE (AT&SF)	BUCKEYE (P. C.)	PASCO (BN)	ROANOKE (N&W)	CENTENNIAL (T&P)	BEOGRAD (YRR)	E. LOS ANGELES (UP)	CALDER (CN)	ALYTH (CP)	SHEFFIELD (SOU)	W. COLTON (SP)	INMAN (SOU)	LANG (D&TSL)	NORTHTOWN (BN)	STRAWBERRY (L&N)	RICE (SCL)	NORRIS (SOU)	BARSTOW (AT&SF)
1	SINGLE LEAD–SINGLE HUMP		X	X				X	X	X	X		X		X	X	X	X	X	X	X	X	X		X	X
2	DUAL LEAD–SINGLE HUMP				X																					
3	DUAL LEAD–DUAL HUMP					X	★					X		X												
4	RECEIVING YARD TRACKS		16	8	9	7	9	18	10	7	5	20	14	11	3	7	20	6	9	1		11	24	28	12	
5	CLASSIFICATION YARD TRACKS		32	50	42	64	70	42	48	40	47	55	44	48	16	34	48	32	56	12	20	63	49	64	56	48
6	DEPARTURE YARD TRACKS		15	8	23	6	18	15	9	8	6	8	9	0	4	8	20	6	12	1		9	14	14	13	
7	CAR RETARDER OPERATOR		X	X	X	X	X	X		X	X	X		X	X			X				X			X	
8	MASTER RETARDER CONTROL		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9	GROUP RETARDER CONTROL		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	✳	X
10	INTERMEDIATE RETARDER CONTROL											X							X							
11	TANGENT RETARDER CONTROL																		X	X						X
12	SKATE RETARDER CONTROL																	X	X			X	X	X		X

★ LAYOUT DESIGNED TO PROVIDE
FOR FUTURE DUAL HUMP

✳ MANUAL CONTROL

	DIGITAL COMPUTER YARDS TABULATION C COMPUTER SYSTEM CONFIGURATIONS	GATEWAY (MOPAC)	EUGENE (SP)	BROSNAN (SOU)	BELLEVUE (N&W)	BAILEY (UP)	PERLMAN (P. C.)	NO. KANSAS CITY (BN)	ARGENTINE (AT&SF)	BUCKEYE (P. C.)	PASCO (BN)	ROANOKE (N&W)	CENTENNIAL (T&P)	BEOGRAD (YRR)	E. LOS ANGELES (UP)	CALDER (CN)	ALYTH (CP)	SHEFFIELD (SOU)	W. COLTON (SP)	INMAN (SOU)	LANG (D&TSL)	NORTHTOWN (BN)	STRAWBERRY (L&N)	RICE (SCL)	NORRIS (SOU)	BARSTOW (AT&SF)
1	SINGLE COMPUTER																			X					X	
2	SINGLE COMPUTER & RELAY BACKUP		X	X	X	X		X			X	X	X	X	X	X					X					
3	SEPARATE OIS COMPUTER(S)																	X	X				X	X		
4	DISTRIBUTED/MULTIPLE PC COMPUTERS						X		X	X							X	X	X			X	X	X		X
5	* 12K COMPUTER MEMORY			X										X	X					X					X	
6	* 16K COMPUTER MEMORY		X		X				X							X		X								
7	* 24K COMPUTER MEMORY					X		X			X	X	X					X			X					
8	* 32K COMPUTER MEMORY																X	X	X			X				
9	HONEYWELL (H-116)		X		X																					
10	GE-PAC ★ 64K COMPUTER MEMORY						★			★	X											X				
11	IBM (S-1800)					X																				
12	HONEYWELL (H-516)							X	X			X	X			X	X									
13	DATA GENERAL														X			X							X	X
14	DEC (PDP 8 & 8I)			X										X												
15	DEC PDP II																			X	X					
16	XEROX (SIGMA 3)																		X							
17	* 48K COMPUTER MEMORY																						X	X		
18	MODULAR COMPUTER CORP (MOD COMP II)																						X	X		
19	COMBINED PC/OIS COMPUTER							X		X							X					X				
20	MULTIPLE OIS COMPUTER									X							X	X					X	X		
21	DATA LINK TO MIS COMPUTER								X			X						X	X			X		X	X	
	* COMPUTER MEMORY SIZE FOR PROCESS																									
	CONTROL (PC) EXCEPT SHEFFIELD AND																									
	WHERE PC AND OPERATING INFORMATION																									
	SYSTEM (OIS) ARE COMBINED																									

	DIGITAL COMPUTER YARDS TABULATION D PERIPHERALS UTILIZED	GATEWAY (MOPAC)	EUGENE (SP)	BROSNAN (SOU)	BELLEVUE (N&W)	BAILEY (UP)	PERLMAN (P. C.)	NO. KANSAS CITY (BN)	ARGENTINE (AT&SF)	BUCKEYE (P. C.)	PASCO (BN)	ROANOKE (N&W)	CENTENNIAL (T&P)	BEOGRAD (YRR)	E. LOS ANGELES (UP)	CALDER (CN)	ALYTH (CP)	SHEFFIELD (SOU)	W. COLTON (SP)	INMAN (SOU)	LANG (D&TSL)	NORTHTOWN (BN)	STRAWBERRY (L&N)	RICE (SCL)	NORRIS (SOU)	BARSTOW (AT&SF)
1	FIXED HEAD DISK		X						2			X	X					X	2				2	2		
2	FIXED HEAD DRUM		X		X		X			X	X					X						X				
3	MOVING HEAD DISK					X		X			X						2					X				
4	CASSETTES																								X	
5	LINE PRINTER					X	X			X	X						2	X				X				
6	CARD READER		X		X	X	X	X		X	X	X	X			X	2		X			X	1	1		
7	CARD PUNCH		X		X	X	X	X		X	X	X	X			X	2		X			X	1	1		
8	CATHODE RAY TUBE (OUTPUT ONLY)							2	3	X	X		2					X	5			X	2	3		
9	CATHODE RAY TUBE (I/O)									X	X		3				7	X				X	3	2		
10	I/O TTY'S ★ (INCLUDING RECEIVING ONLY)		7	X	4	5	X	5	7	X	X	5	5	X	X	3	12	X	2	X	3	X	5	3	X	
11																										
12	WEIGH-IN-MOTION SCALE INPUT		X						X				X			X	X	X	X			X	X	X		
13	ACI'S AS INPUT TO PROCESS COMPUTER								1				1			1	10									
14	PAPER TAPE READER/ PUNCH																			X	X					
15	NOTE *								*	*		*							*		*		*	*		

* DOES NOT INCLUDE PERIPHERALS
FOR OIS EXCEPT FOR COMBINED
PC/OIS CONFIGURATION

★ I/O TTY IS INPUT /OUTPUT
TYPEWRITER

	DIGITAL COMPUTER YARDS TABULATION E INVENTORY SOFTWARE	GATEWAY (MOPAC)	EUGENE (SP)	BROSNAN (SOU)	BELLEVUE (N&W)	BAILEY (UP)	PERLMAN (P. C.)	NO. KANSAS CITY (BN)	ARGENTINE (AT&SF)	BUCKEYE (P. C.)	PASCO (BN)	ROANOKE (N&W)	CENTENNIAL (T&P)	BEOGRAD (YRR)	E. LOS ANGELES (UP)	CALDER (CN)	ALYTH (CP)	SHEFFIELD (SOU)	W. COLTON (SP)	INMAN (SOU)	LANG (D&TSL)	NORTHTOWN (BN)	STRAWBERRY (L&N)	RICE (SCL)	NORRIS (SOU)	BARSTOW (AT&SF)
1	NO INVENTORY			X										X	X					X					X	
2	ADVANCE CONSIST		X			X	X			X	X						X	X				X	X	X		
3	RECEIVING YARD CONSIST		X			X	X	X		X	X						X	X	X			X	X	X		
4	HUMP LEAD CONSIST		X		X	X	X	X	X	X	X	X	X			X	X	X	X		X	X	X	X		
5	CLASSIFICATION YARD CONSIST		X		X	X	X	X	X	X	X		X				X	X				X	X	X		
6	DEPARTURE YARD CONSIST		X			X		X			X						X	X				X	X	X		
7	AS HUMPED LIST		X			X	X		X	X	X	X					X	X	X			X	X	X		
8	INDUSTRY YARDS (LOCAL)							X									X						X	X		
9	SCALE TICKET/CARD OUTPUT		X								X						X	X				X	X	X		
10	AUTOMATIC TRIM																X	X				X	X			
11	ACI PROCESSING								X		X	X	X			X	X					X				
12	REAL TIME OPERATING SYSTEM									X	X							X	X			X	X	X		
13	SEE NOTE *								*			*							*		*					

* ALL OIS FUNCTIONS PERFORMED
BY COMPUTER EXTERNAL TO
YARD COMPUTER

DIRECTORY
CONSULTING ENGINEERS

FRANK R. WOOLFORD

Engineering Consultant—Railroads

24 Josepha Ave.
San Francisco, Ca. 94132
(415) 587–1569

246 Seadrift Rd.
Stinson Beach, Ca. 94970
(415) 868–1555

Westenhoff & Novick, Inc.

Consulting Engineers

Civil—Mechanical—Electrical

Fixed & Movable Bridges
Soils, Foundations, Buildings
Structural & Underwater Investigations
Planning, Feasibility, Design, Inspection

222 W. Adams St., Chicago, Ill. 60606

New York Washington Panama

HAZELET & ERDAL

Consulting Engineers

Design Investigations Reports
Fixed and Movable Bridges

150 So. Wacker Dr., Chicago, Ill. 60606
Louisville Cincinnati Washington

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF

Feasibility studies and design services for

Bus and rail transit	Terminals
Regional and urban planning	Parking
Soils and foundations	Tunnels
Structures	Utilities
Environmental impact studies	

Offices in 26 cities 816 474-4900
1805 Grand Avenue, Kansas City, Missouri 64108

KIRKHAM MICHAEL

Consulting Engineers

Bridges, Relocations, Land Development

Omaha • Minneapolis • Rochester
Fargo • Sioux Falls

CLARK, DIETZ AND ASSOCIATES–ENGINEERS, INC.

Consulting Engineers

Bridges Structures, Foundations, Industrial Wastes and Railroad Relocation

211 No. Race St., Urbana, Ill.

Sanford, Fla. Memphis, Tenn.
Jackson, Miss. St. Louis, Mo.
Chicago, Ill.

MODJESKI AND MASTERS

Consulting Engineers

Design, Inspection of Construction & Inspection of Physical Condition of Fixed & Movable Railroad Bridges

P.O. Box 2345, Harrisburg, Pa. 17105
1055 St. Charles Ave., New Orleans, La.

HARDESTY & HANOVER

Consulting Engineers

MASS TRANSPORTATION

Highways • Railways
Bridges—Fixed and Movable
Design • Resident Inspection
Studies • Appraisals

101 Park Ave., New York, N. Y. 10017

THOMAS K. DYER, INC.

Consulting Engineers

Railroads—Transit Systems
Track, Signals, Structures

Investigations and Feasibility Reports
Planning, Design, Contract Documents

1762 Massachusetts Avenue
Lexington, Mass. 02173

DCO The De Leuw, Cather Organization

CONSULTING ENGINEERS
165 W. WACKER DRIVE • CHICAGO 60601

SUBWAYS • RAILROADS • PUBLIC TRANSIT
TRAFFIC • PARKING • HIGHWAYS
BRIDGES • PORT DEVELOPMENT • AIRPORTS
COMMUNITY PLANNING • URBAN RENEWAL
MUNICIPAL WORKS • INDUSTRIAL BUILDINGS
ENVIRONMENTAL SCIENCE AND ENGINEERING

ATLANTA • BOSTON • BUFFALO • NEWARK • NEW YORK
OKLAHOMA CITY • PHILADELPHIA • SAN FRANCISCO • SEATTLE
WASHINGTON, D.C. • BANGKOK • BEIRUT • SYDNEY

IECO

INTERNATIONAL ENGINEERING COMPANY, INC.

CONSULTING ENGINEERS

RAILWAYS HIGHWAYS
BRIDGES TUNNELS
ROUTE LOCATION
SHOP FACILITIES

(415) 397-4071
CABLE • INTERENGCO 220 MONTGOMERY ST.
SAN FRANCISCO • CALIFORNIA 94104

RILEY, PARK, HAYDEN & ASSOCIATES, INC.

Consulting Engineers

Survey Services, Photogrammetry, General Civil, Bridges, Railroads & Industrial Park Design.

136 Marietta St., N. W.
Atlanta, Georgia 30303
(404) 577–5600

Engineers

Designers Planners

PARSONS BRINCKERHOFF QUADE DOUGLAS

Route Location, Shop Facilities, Container/Bulk Cargo, Handling Utilities, Bridges, Tunnels, Evaluations, Appraisals, Supervision

ONE PENN PLAZA, NEW YORK, NY 10001

Boston • Denver • Honolulu
San Francisco • Trenton

RALPH WHITEHEAD & ASSOCIATES

Consulting Engineers

Bridges, Buildings, Highways,
Railroads, Airports

1945 RANDOLPH ROAD
CHARLOTTE, NORTH CAROLINA 28207

R.W. BOOKER & ASSOCIATES, INC.

ENGINEERS ARCHITECTS PLANNERS

1139 OLIVE ST. ST. LOUIS, MISSOURI 63101

LEXINGTON, KENTUCKY FORT WORTH, TEXAS

PORTER AND RIPA ASSOCIATES, INC.

ENGINEERING·PLANNING·ARCHITECTURE

Design · Inspections · Reports
Planning · Structures
Environmental Studies

200 Madison Avenue, Morristown, New Jersey 07960

SVERDRUP & PARCEL AND ASSOCIATES, INC.
800 No. Twelfth Blvd. St. Louis, Mo. 63101

Sverdrup & Parcel

- *DESIGN*
- *PLANNING*
- *CONSTRUCTION MANAGEMENT*

Boston, Charleston, Gainesville, Jacksonville,
Nashville, New York, Phoenix,
San Francisco, Seattle, Washington, D.C.

CONSULTING ENGINEERS

SOROS ASSOCIATES

Consulting Engineers

Transfer Terminals & Ports For Dry Bulks,
Liquids & Containers—Waterfront Structures
Materials Handling Systems

575 Lexington Ave.
New York, N. Y. 10022
(212) 421–0400

Rio de Janeiro Santiago, Chile
Sydney, Australia

R. G. "SLIM" SIMMONS

Railroad Consultant

3009 George St.
Franklin Park, Ill. 60131
(312) 678–7321

30 Jackson St.
Denver, Colo. 80206
(303) 321–0902

THE KEN R. WHITE COMPANY
TOTAL CONCEPT
ENGINEERING SERVICE

- BRIDGES—FOUNDATIONS
- ENVIRONMENTAL STUDIES
- FEASIBILITY STUDIES
- PHOTOGRAMMETRY—MAPPING
- PLANNING—INDUSTRIAL PARK
- RELOCATIONS
- TRANSPORTATION

3955 E. Exposition Avenue
Denver, Colorado 80209
Phone (303) 744-1861

HELENA • PHOENIX • ATLANTA • MIAMI • HONOLULU

McCormick, Taylor and Associates, Inc.

Consulting Engineers

Structural • Transportation
Public Works • Support Service

351 E. Conestoga Rd.
Strafford, Pa. 19087
(215) 687-6311

Suburban Station Bldg.
Philadelphia, Pa. 19103
(215) LO 9-2400

A. J. HENDRY, INC.
CONSULTING ENGINEERS

SIGNALS • COMMUNICATIONS • AUTOMATION • ELECTRIFICATION
RAILROADS • RAIL TRANSIT

SUITE 810 OSBORN BUILDING
ST. PAUL, MINNESOTA 55102
(612) 222 2787

SPAULDING ENGINEERING CO.

CONSULTING ENGINEERS
MEMBER
AMERICAN CONSULTING ENGINEERS COUNCIL

1821 UNIVERSITY AVENUE
ST. PAUL, MINNESOTA 55104
PHONE 612/644–5676

TURNER ENGINEERING COMPANY

(SAWYER–PIEPMEIER)

RAILROAD ENGINEERING

306 GAY ST.
NASHVILLE, TENNESSEE 37201
615–244–2144
ALBANY, NY 518–456–1994

GOOD TRACK GOOD SERVICE

COAST TO COAST...

Let Speno show you the way to get significantly more ton miles of service from your rails. Send for FREE Booklets on Speno Ballast Cleaning and Speno Rail Grinding.

Ballast Cleaning • Rail Grinding

"Just Ask the Railroads That Use Our Services"

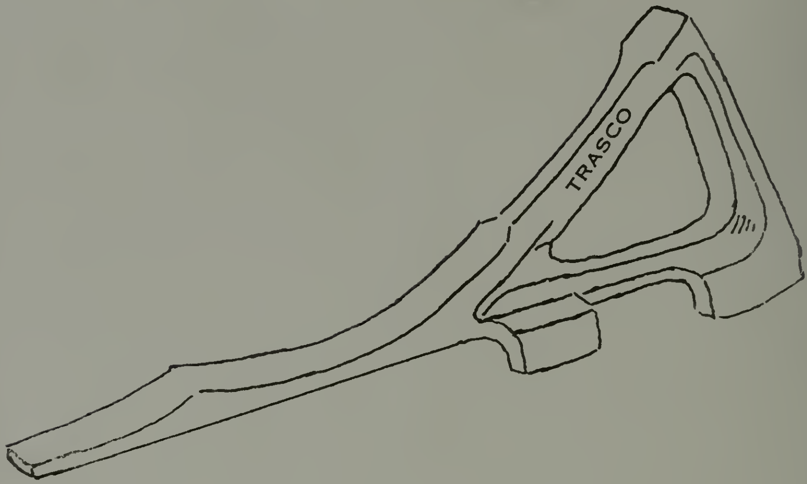
Frank Speno Railroad Ballast Cleaning Company, Inc.
306 North Cayuga St., Ithaca, New York 14850
Clark St., Box 219 East Syracuse, New York 13057

Speno International, S. A.
22 Parc Chateau Banquet, Geneva, Switzerland
(For Rail Grinding Outside the North American Continent)

MEMBER RPI

IEC-Holden Ltd.
8180 Côte de Liesse Road.,
Montreal, 376 P. Q., Canada

TRASCO Track Skates



Preferred by skatemen
Light
Tough
Balanced hand hold
No curl tongue

TRACK SPECIALTIES
COMPANY
Box 729 Westport, Conn.

J. E. Stallmeyer

RECEIVED
MAR 11 1975
J. E. STALLMEYER

American Railway Engineering Association—Bulletin

Bulletin 651
Proceedings Volume 76*

January–February 1975

CONTENTS

REPORTS OF COMMITTEES

Roadway and Ballast (1) ---- 279
Buildings (6) ---- 299
Timber Structures (7) ---- 315
Concrete Structures and Foundations (8) ---- 319
Economics of Plant, Equipment and Operations (16) ---- 325
Economics of Railway Construction and Maintenance (22) ---- 327
Environmental Engineering (13) ---- 341
Steel Structures (15) ---- 351
Maintenance of Way Work Equipment (27) ---- 353
Clearances (28) ---- 361
Systems Engineering (32) ---- 363
Engineering Education (24) ---- 373
Electrical Energy Utilization ---- 383
Rail (4) ---- 405
Track (5) ---- 409
Scales ---- 415
Ties and Wood Preservation (3) ---- 417

KANSAS CITY REGIONAL MEETING

Address—Roadbed Stabilization—Various Methods, by J. B. Farris ---- 419
Address—New Vertical Lift Bridge Over Chicago's Calumet River, by R. F. Beck ---- 432
Address—Concrete Repair by Epoxy Injection, by B. J. King ---- 435
Addresses—A Planning, Scheduling and Reporting System for MW&S Basic Force, by R. G. Brohaugh and D. D. Thomas ---- 437
Directory of Consulting Engineers ---- 446–1

---

[*] Proceedings Volume 76 (1975) will consist of AREA Bulletins 649, September–October 1974; 650, November–December 1974; 651, January–February 1975; and 653, June–July 1975 (Technical Conference Report issue). Blue-covered Bulletin 652, April–May 1975 (the Directory issue), is not a part of the Annual Proceedings of the Association.

BOARD OF DIRECTION
1974–1975

President

R. F. Bush, Chief Engineer, Erie Lackawanna Railway, Midland Bldg., Cleveland, OH 44115

Vice Presidents

J. T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, 500 Water St., Jacksonville, FL 32202
W. J. Jones, Engineer Maintenance of Way and Structures, System, Southern Pacific Transportation Company, 1 Market St., San Francisco, CA 94105

Past Presidents

R. M. Brown, Chief Engineer, Union Pacific Railroad, 1416 Dodge St., Omaha, NE 68179
D. V. Sartore, Chief Engineer—Design, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101

Directors

B. G. Anderson, Assistant Vice President—Engineering, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101
John Fox, Assistant Chief Engineer, Canadian Pacific Rail, Windsor Station, Montreal, PQ H3C 3E4
C. E. Weller, Assistant Vice President—Engineering, Chicago, Rock Island & Pacific Railroad, LaSalle St. Station, Chicago, IL 60605
B. J. Gordon, Chief Engineering Officer, Penn Central Transportation Company, 6 Penn Center Plaza, Room 1640, Philadelphia, PA 19104
R. W. Pember, Chief Engineer, Design and Construction, Louisville & Nashville Railroad, P. O. Box 1198, Louisville, KY 40201
E. Q. Johnson, Senior Assistant Chief Engineer, Chessie System, P. O. Box 1800, Huntington, WV 25718
W. E. Fuhr, Assistant Chief Engineer—Staff, Chicago, Milwaukee, St. Paul & Pacific Railroad, Union Station, Room 898, Chicago, IL 60606
B. E. Pearson, Chief Engineer, Soo Line Railroad, Soo Line Bldg., Room 1520, Minneapolis, MN 55440
P. L. Montgomery, Manager Engineering Systems, Norfolk & Western Railway, 8 N. Jefferson St., Roanoke, VA 24011
E. C. Honath, Assistant General Manager Engineering, Western Lines, Atchison, Topeka & Santa Fe Railway, 900 Polk St., Amarillo, TX 79171
Mike Rougas, Chief Engineer, Bessemer & Lake Erie Railroad, P. O. Box 471, Greenville, PA 16125
J. W. DeValle, Chief Engineer Bridges, Southern Railway System, 99 Spring St., S. W., Atlanta, GA 30303

Treasurer

A. B. Hillman, Jr., Chief Engineer, Belt Railway of Chicago, 6900 S. Central Ave., Chicago, IL 60638

Executive Director

Earl W. Hodgkins, 59 E. Van Buren St., Chicago, IL 60605

Assistant to Executive Director

N. V. Engman, 59 E. Van Buren St., Chicago, IL 60605

Administrative Assistant

D. F. Fredley, 59 E. Van Buren St., Chicago, IL 60605

Published by the American Railway Engineering Association, Bi-Monthly, January–February, April–May, June–July, September–October and November–December, at
59 East Van Buren Street, Chicago, Ill. 60605

Second class postage at Chicago, Ill., and at additional mailing offices.
Subscription $15 per annum

Copyright © 1975
by the
American Railway Engineering Association
All rights reserved.

No part of this publication may be reproduced, stored in an information or data retrieval system, or transmitted, in any form, or by any means—electronic, mechanical, photocopying, recording, or otherwise—without the prior written permission of the publisher.

Report of Committee 1—Roadway and Ballast

E. L. Robinson,
Chairman

N. E. Whitney,
Vice Chairman

W. J. Sponseller,
Secretary

M. B. Hansen
F. L. Peckover
C. E. Webb
J. L. Vickers
W. M. Dowdy
R. L. Williams
J. B. Farris
J. A. Goforth
H. C. Archdeacon
A. G. Altschaeffl
R. D. Baldwin
H. E. Bartlett
C. W. Bean
R. H. Beeder (E)
C. R. Bergman
J. R. Blacklock
R. H. Bogle, Jr.
E. W. Burkhardt
B. E. Butterbaugh
R. M. Clementson
D. H. Cook
M. W. Cox
G. W. Deblin
J. W. Dykes
H. K. Eggleston
G. E. Ellis
W. P. Eshbaugh (E)
E. E. Farris
G. C. Fenton
J. S. Fluke
F. B. Grant
R. T. Haggerstrom
W. T. Hammond
R. D. Hellweg
T. J. Hernandez
P. R. Houghton
H. O. Ireland
G. Jess
B. J. Johnson
D. N. Johnston
J. H. Kirch
J. A. Kuhn
H. W. Legro (E)
W. S. Lovelace
K. J. Ludwig
J. K. Lynch
F. H. McGuigan
H. E. McQueen
B. C. Mohl
W. G. Murphy
J. E. Newby
F. P. Nichols
G. F. Nich
R. V. Perrone
R. H. Peterson
W. B. Peterson
S. R. Pettit
H. E. Richards
G. D. Santolla
P. J. Seidel
W. M. Snow
E. H. Steel
W. M. Stumm
F. A. Tijan, Jr.
R. H. Uhrich
M. E. Vosseller
J. B. Wackenhut
A. J. Wegmann (E)
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Roadbed

   Tentative recommended practice for maintenance of roadbed, Section 1.4, is presented as information .... page 280

2. Ballast

   The importance of the ballast section is amplified by the use of heavier cars. The need for more representative laboratory testing is recognized, new test procedures will be investigated and those worthy of consideration will be reported on.

3. Natural Waterways

   The committee is reviewing Manual material on Prevention of Erosion for possible revision and updating.

4. Culverts and Drainage Pipe

   Through cooperative effort with Committee 15, recommended specifications for steel tunnel liner plates, as published in AREA Bulletin 645, November–December 1973, are now ready for publishing as Manual material.

5. Pipelines

   Consideration is being given to providing recommendations for use of casing pipe larger than 42-inch diameter. The committee has advice that casings of 96-inch diameter have been installed, and recommended specifications may be needed to cover large casing pipe.

6. Fences

   The committee finds that there is a need for security fence recommended specifications. Information is being collected in this area.

7. Tunnels

   A preliminary revision has been prepared updating the entire portion of the Manual and the committee proposes to include a new section on increasing tunnel clearances.

8. Vegetation control

   Revision of present Manual material, pages 1–9–1 through 1–9–14, was submitted for adoption and published in Part 1 of Bulletin 650, November–December 1974.

THE COMMITTEE ON ROADWAY AND BALLAST,
E. L. ROBINSON, *Chairman.*

Paul McKay
1887-1973

Paul McKay, retired division engineer, New York, Chicago & St. Louis Railroad (now part of the Norfolk & Western Railway), died Saturday, May 5, 1973, in City Hospital, Meadville, Pa., after a short illness.

Born at Meadville on October 18, 1887, he was a graduate of Meadville High School and graduated from Allegheny College in 1912. During the summers, Mr. McKay was a locomotive fireman on the Bessemer & Lake Erie Railroad from 1908 to 1910.

Nearly all of Mr. McKay's working life was spent in the field of engineering. In 1913, he joined the New York, Chicago & St. Louis Railroad as an instrumentman and in 1934 was appointed division engineer, the position he held until retirement in 1955.

Mr. McKay joined the American Railway Engineering Association on March 27, 1926, becoming a Life Member in 1955 upon his retirement from the Nickel Plate. He was a member of Committee 1 from 1938 to 1958 and was bestowed the honor of Member Emeritus in 1958 as a result of his outstanding contributions to the committee and the AREA.

Paul McKay is remembered by his associates as a railroad engineer from the old school. His great wealth of knowledge, in this field, was highly respected.

From 1960 to 1970, he was involved in development of oil and gas products in five northeastern counties of Pennsylvania.

Mr. McKay was a veteran of World War I, serving as a first lieutenant in Company A, 3rd Corps Artillery, American Expeditionary Forces in France. He was a member of Christ Church, Episcopal; The American Legion; Masonic Lodge 408 of Meadville, a charter member of Field and Sea Masonic Lodge in France; a chapter, council and commandary member of Knights Templar and Coudersport Consistory and was a 32nd degree Mason. He was also a member of Phi Kappa Psi.

We of Committee I knew Paul as a dedicated engineer; his other many friends will also remember him as one who was firm in his support of everything that stood for value and quality; a man of the soundest judgement, reasoned convictions and of unqualified integrity.

Report on Assignment 1

Roadbed

F. L. Peckover *(chairman, subcommittee)*, D. H. Cook, G. W. Deblin, W. P. Eshbaugh, H. O. Ireland, H. W. Legro, F. H. McGuigan, W. G. Murphy, J. E. Newby, S. R. Pettit, P. J. Seidel, W. M. Snow, J. R. Blacklock.

The following report on roadbed maintenance is presented as information. Comments and criticisms are invited. The committee proposes to present the recommended practice for adoption and publication in the Manual to complete revision of Part 1—Roadbed, and add to the present Manual material.

PART 1—ROADBED

CONTENTS

1.4 MAINTENANCE

- 1.4.1 Maintenance of Roadbed
  1. Types of Instability
  2. Subgrade Pumping
  3. Softening and Squeezing of Subgrade
  4. Frost Heaving
     1. Causes and Occurrences
     2. Track Betterment
     3. Replacement of Frost Heaving Material
     4. Drainage
     5. Use of Salt
     6. Track Shimming
- 1.4.2 Maintenance of Rock Slopes
  1. Rock Falls
  2. Methods of Treatment
  3. Planning
- 1.4.3 Maintenance of Earth Slopes
  1. Types of Maintenance Required
  2. Restoration of Roadbed Shoulders
  3. Restoration of Earth Slopes
     1. Basic Principles
     2. Planning
     3. Methods
- 1.4.4 Widening of Cuts
  1. Rock Cuts
  2. Earth Cuts
- 1.4.5 Drainage and Erosion Control
  1. Ditches and Drains
  2. Erosion Control

    3. Seeding and Sodding
    4. Filter Layers
    5. Filter Cloths

1.4.6 Methods of Opening Snow Blockades
    1. General
    2. On Line
    3. In Yards and Terminals

References

1.4 MAINTENANCE

1.4.1 MAINTENANCE OF ROADBED

1.4.1.1 Types of Instability

Unstable or uneven track may be caused by roadbed conditions including:

- pumping of subgrade soils into the ballast,
- softening and lateral movement of subgrade soils in the presence of water,
- frost heaving of subgrade soils.

The first two conditions are aggravated by increases in speed, frequency or weight of traffic. Frost heaving is independent of traffic.

1.4.1.2 Subgrade Pumping (see also Article 1.2.5.3)

Saturated subgrade soils may be pumped up into the voids of ballast by repetitive traffic loads. Fine sands, silts and clays are susceptible to pumping when water is present. In new construction and in major track upgrading to carry increasing traffic, such pumping action is reduced by using a layer of compacted subballast material graded to act as a filter.

In existing track, pumping occurs most frequently under poorly maintained rail joints. Muddy ballast at a rail joint should not, however, be assumed as a sign of subgrade pumping. Such fouling is sometimes caused by internal abrasion of the ballast pieces under heavy dynamic loads. On main lines in particular, old gravel and ballast underlying more recently placed crushed ballast material seems to form an effective filter against upward pumping of the subgrade. Cause of ballast fouling should be checked by excavation into the ballast section before remedial action is chosen.

Subgrade pumping can only be eliminated by holding the unstable soil in place. This can be done by:

(1) Removing the fouled ballast and reconstructing the track using a subballast layer to act as a filter.

(2) Laying a membrane unnder the ballast, protected by an overlying layer of well-graded sand. Such a membrane must be tough and permanent; polyvinyl chloride and woven plastic materials are used successfully. With careful planning the membrane can be installed during a ballast-cleaning operation. Under severe shock loading conditions such as at diamond crossings, a membrane may be preferred to a filter layer.

(3) Applying a bituminous spray to the area under pumping joints before the ballast is replaced during a ballast cleaning operation (Ref. 1).

The application of more top ballast without removal of the fouled ballast is not recommended as pumping will in time foul the new ballast as well.

1.4.1.3 Softening and Squeezing of Subgrade

Areas where track settles repeatedly under traffic, requiring periodic surfacing, are sometimes called "soft spots." The settlement of track will be accompanied by soil squeezing up between the ties or out at the track shoulders, or bulging on the roadbed slopes.

Soft spots usually occur where there are plastic subgrade soils, water trapped in the roadbed, and heavy traffic. Soft spots usually develop as follows:

(1) When track is laid on plastic subgrade soil which is not well compacted or stabilized, traffic loads will cause a depression to form under each tie, capable of holding free water.

(2) As the water cannot evaporate, it remains in these depressions, and softens and weakens the plastic soil.

(3) Overstressed by traffic loads under the ties, the soil squeezes up to a position of lower stress between ties, or, where there is sufficient thickness of ballast to prevent this, moves laterally to the track shoulder.

(4) In either case a ridge of impermeable soil is raised around each depression or ballast pocket, which is thus capable of holding a large amount of water. Clay at the base of the ballast pockets continues to soften and squeezes out of position, making the condition self-perpetuating.

If track can be taken out of service temporarily, and the cost is warranted, soft spots and ballast pockets can be cured by:

(1) Excavation and replacement of the plastic subgrade soil with more stable soil (Article 1.2.5.).

(2) Stabilization of the subgrade soil with an additive such as lime or concrete (Article 1.2.3.5.).

(3) Introduction of a surface cap of stone screenings or similarly graded material on the top of subgrade to reduce the amount of rainfall reaching the subgrade.

(4) Introduction of a waterproof membrane at the surface of subgrade to prevent it from becoming saturated (Article 1.2.5.3.).

If track cannot be taken out of service, soft spots and ballast pockets can be improved by one of:

(1) Drainage of the subgrade if water can be drained to a level lower than the base of the ballast pockets. The method of drainage should be based on a field investigation. Drainage pipes usually silt up. Excavation of track shoulders and replacement with pervious materials graded to act as a filter may offer relief.

(2) Stabilizing the subgrade soil with cement grout according to the procedure given in AREA Proceedings, Vol. 53, 1952, pages 736–742.

(3) Stabilizing the subgrade by the controlled addition of lime if conditions and subgrade soils are suitable. Consulting advice should be obtained.

(4) Driving of poles or ties vertically in rows along the end of track ties, if conditions are suitable. The procedure is described in AREA Proceedings, Vol. 55, 1954, pages 637–638.

1.4.1.4 Frost-Heaving

1.4.1.4.1 Causes and Occurrence

Frost-heaving of roadbed and ballast is caused by the simultaneous presence of fine-grained material, water and freezing temperatures, as outlined in Article 1.2.5.5.

All moist soils increase in volume on freezing, but significant volume changes occur only when lenses of ice grow in the soils. Rough track is caused when differences in volume change of subgrade soils develop over short distances along or across the track.

These differences may be *more* or *less* than the average heaving of the track. *More* heaving than average (rise in track) occurs typically at farm and road crossings; *less* heaving than average (dip in track) occurs typically at culverts, and road crossings where salt is applied. A change from a heaving to a non-heaving condition may occur at bridge approaches or at the end of rock cuts. A good proportion of all types of heaving occurs in regular track where no particular features are present but a change in subgrade soil occurs. Before deciding on treatment it is most important to determine, by sighting along the track, whether the problem is created by a rise or a dip in the track.

Rough track, caused by frost-heaving, causes excessive wear on both track and rolling stock and involves the danger of accidents unless slow orders are applied or track conditions improved. The most common method of improving the track surface is by the temporary shimming of ties. However, this is expensive, reduces the service life of wood ties, and requires an experienced labor force to be kept on hand, particularly at the start of freezing and thawing seasons when heaving and subsidence occur relatively suddenly. Concrete ties cannot be shimmed more than a small amount. For these reasons, methods of preventing track-heaving from developing should be considered as an alternative to temporary shimming.

1.4.1.4.2 Track Betterment

Frost-heaving under track may be reduced or made more uniform by influencing one or more of the conditions causing it. This may occur as a side effect of work done primarily to improve other track conditions:

(1) Cleaning of fouled ballast will remove fine-grained dirt and reduce capillary rise of water.

(2) Addition of a ballast lift will reduce frost penetration into subgrade soil.

(3) Addition of bank-widening material may reduce frost penetration into track shoulders.

While beneficial, the overall effect of these measures on frost-heaving is limited. Where heaving of track must be eliminated, a more direct approach to the problem is required.

1.4.1.4.3 Replacement of Frost-Heaving Material

Although expensive under an operating track, replacement of frost-susceptible subgrade soil with non-heaving material is a reliable and permanent method of eliminating the problem. Steps to be taken are:

(1) When frost-heaving and shimming are at a maximum in early spring, find by sighting along track whether the trouble spot is caused by a rise or a dip in the track. Mark the location exactly according to the procedure shown in Fig. 1.4.1. At the same time, excavate to find the maximum frost depth.

(2) After all frost is out of the ground, remove track and excavate over the length of section (A) in Fig. 1.4.1 to remove the subgrade soil to a depth

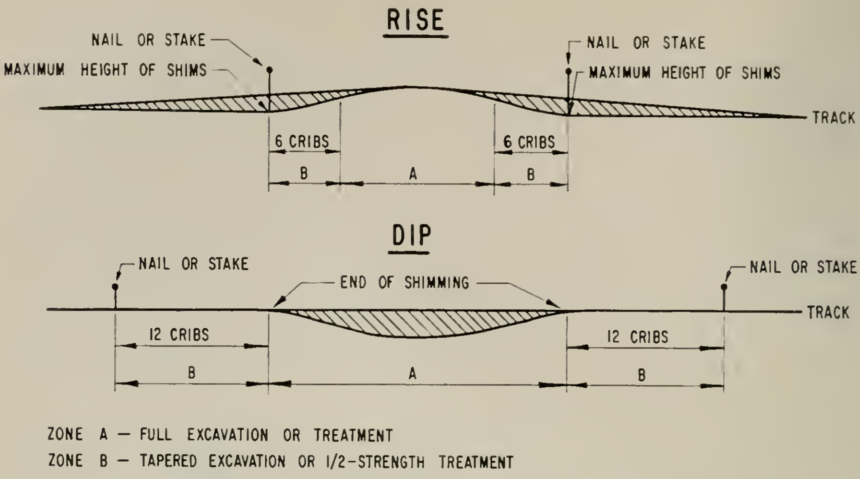


Fig. 1.4.1—Method of marking track for treatment of frost-heaving.

of 60% of the maximum frost depth. In both transition zones (B), taper the excavation uniformly to zero at the outer ends. Carry the excavation to the shoulders for proper drainage.

(3) Backfill to grade level with thoroughly compacted layers of non-heaving material (see Article 1.2.5.5 and Column 4 of Table 1.2.5).

(4) Replace subballast, ballast and track.

Under special or extreme conditions, the installation of a layer of insulating material in the roadbed should be considered.

1.4.1.4.4 Drainage

If ditches are less than about 4 ft below top of subballast or if water pockets exist under the track, the improvement of drainage can reduce track-heaving if the water table can be significantly lowered. Depending on site conditions, improvements can include deepening of side ditches, or excavation and replacement of track shoulder materials with clean granular material to a depth sufficient to ensure drainage of water pockets under track (not a permanent solution).

1.4.1.4.5 Use of Salt

The controlled application of cheemicals can reduce heaving of track economically and reasonably effectively. Many chemicals have been tried for this purpose and ordinary crushed rock salt (NaCl) is found most suitable.

The procedure shown in Fig. 1.4.1 must be used to show where the salt is to be applied. A small quantity of salt is more effective than a larger quantity. It has no undesirable side effects and is effective for two winters. The method is detailed in Ref. 2.

1.4.1.4.6 Track Shimming

Shimming is done to restore track surface and level to a safe condition. For the purpose, wood shims are installed on the top of ties which remain too low during track heaving. Shimming in no way reduces frost heaving and must therefore be done every winter. Procedures used to shim track are given in Chapter 5, Track.

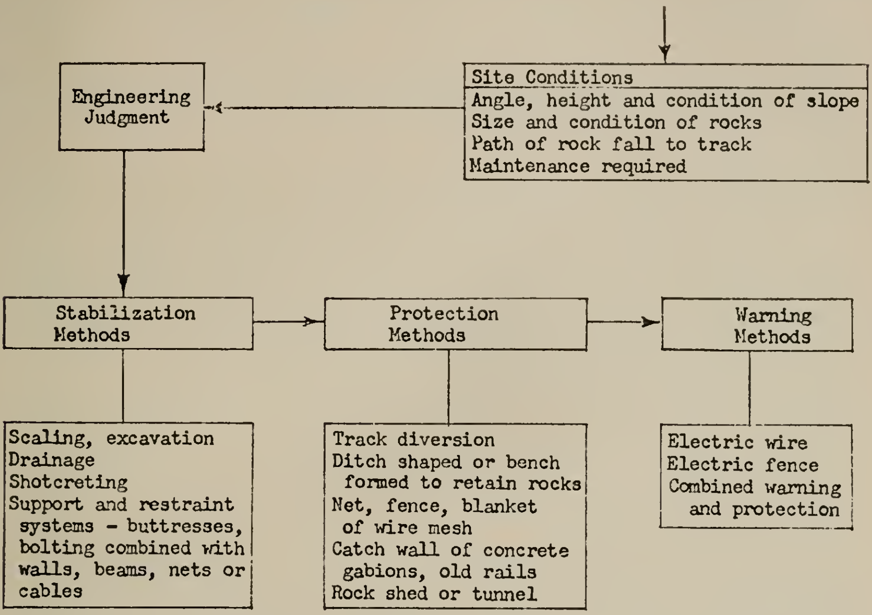

Site Conditions
Angle, height and condition of slope
Size and condition of rocks
Path of rock fall to track
Maintenance required
Engineering Judgment
Stabilization Methods
Protection Methods
Warning Methods
Scaling, excavation
Drainage
Shotcreting
Support and restraint systems - buttresses, bolting combined with walls, beams, nets or cables
Track diversion
Ditch shaped or bench formed to retain rocks
Net, fence, blanket of wire mesh
Catch wall of concrete gabions, old rails
Rock shed or tunnel
Electric wire
Electric fence
Combined warning and protection

Fig. 1.4.4—Procedure in choosing treatment at site of rock fall.

1.4.2 MAINTENANCE OF ROCK SLOPES

1.4.2.1 Rock Falls

Rock falls occur in cuts and on sidehill portions of railway lines in rough terrain. Where rock faces have been exposed for a number of years, single rocks or small groups of rocks are usually involved rather than the failure of entire slopes. For this reason, accurate prediction of rock falls is not possible. However, an experienced person can assess the risk of rock falls at particular locations in a general way.

Rock falls incur costs due to the regular maintenance work involved, track patrols, train delays and rerouting required, and of course damage to equipment, injuries and sometimes deaths are incurred. The cost of protection cannot be justified as a return on investment; safety is the main concern.

1.4.2.2 Methods of Treatment

From an analysis of site conditions and performance, the most suitable treatment of a dangerous rock slope can be chosen. Methods of treatment should be considered in the following priority if the danger of rock falls is to be reduced:

(1) Stabilization, or preventing rocks from moving out of place unexpectedly (as with rock scaling and rock pinning or bolting).

(2) Protection of track, or keeping rocks which do move out of place from reaching the track (as with walls or rock sheds).

(3) Warning traffic when rocks arrive in the vicinity of track (as with electric warning fences).

Stabilization and protection measures offer a positive solution to the problem and the latter can be combined with warning methods. Warning methods by themselves have no effect on the causes of danger.

The recommended approach to a rock fall problem at a particular site is shown in Fig. 1.4.4. Methods are explained in Ref. 3.

1.4.2.3 Planning

Remedial work should be planned by railway engineering staff with particular experience in rock-fall problems, using consulting advice where needed.

Good records are the basis for good planning and priorities. Records should include the time and exact location of accidents and delays to traffic, of all rocks found on track, and of the removal of ditch debris, as well as plans and maintenance required for all stabilization and protection installations.

A regular annual inspection should be made, preferably with an experienced consultant, to appraise hazards and decide on action and priorities required. Rock work is best done by experienced contractors, with a contract drawn up to allow flexibility in the work if conditions are found to be different than expected.

1.4.3 MAINTENANCE OF EARTH SLOPES

1.4.3.1 Types of Maintenance Required

Slopes of fills and cuts along the railway right-of-way are subject to the continuing effects of gravity and running water. As a result, periodic maintenance is required to restore roadbed shoulders, clean ditches, fill gullies and prevent erosion by rain, waves or currents. Emergency maintenance operations are required if failure of the roadbed, or earth slopes above or below track, endangers traffic.

Some of these maintenance operations are discussed elsewhere:

- protection against erosion by waves and currents, Part 3, this chapter.
- protection against erosion by rain and seepage, Article 1.4.5.

1.4.3.2 Restoration of Roadbed Shoulders

Roadbed shoulders become too narrow with time to support the full ballast section. This results from the settlement of roadbed, requiring track to be raised, or from erosion and gullying of the shoulders. Restoration of the roadbed shoulders (bank widening) is frequently required before ballast can be added and retained on the edges of the roadbed. It plays an important part in strengthening the roadbed to carry the wide, deep ballast sections required for heavier wheel loads and more frequent traffic.

Planning for shoulder restoration includes the work of extending culverts to the new limits of fills, and the choice of suitable material and filling and placement methods. Particular care should be taken that the pattern of natural drainage is maintained. Shoulder restoration work is usually done well in advance of subsequent track improvements.

Materials should be stable and erosion-resistant (see Column 7 in Table 1.2.5). Pervious fills should only be bank-widened with pervious soils so that fill drainage can take place.

After culverts are extended, vegetation and organic matter should be cleared from the slope and foundation area on which fresh material is to be placed to avoid potential sliding planes. This is particularly important with sidehill fills. The original slope materials should be benched and blended with each layer of new fill to obtain a good bond. The roadbed shoulder should be graded as uniformly as possible and sloped outward so that rainfall may drain out of the ballast and not form channels and gullies in the fill shoulder.

Suitable material for shoulder restoration may be available from side borrow or from adjacent cuts, thereby improving drainage and flattening cut slopes at the same time. Material should be chosen to be at a water content generally suitable for compaction. Excessively wet material should not be used. Hauling can be done with scrapers, placing material in horizontal layers, working up from the toe of the existing fill. Bulldozers can trim the material to a final slope of about 2 to 1.

If material is hauled in by train and dumped down the slope, the material should be spread in layers and shaped by bulldozers working back and forth and up and down the bank to a final slope of about 2 to 1. In no case should the new material be left at the angle of repose. This decreases the stability of the original 'slope which carries the new fill, and leads to rapid settlement and erosion of the new material.

In all cases the new fill should be compacted from bottom to top with at least two complete coverages of bulldozer treads, and left with a smooth uniform surface. Where the width of the fill will allow, a more satisfactory job will be obtained by the use of regular compaction equipment.

The stability of fills with weak foundations should be checked before bank widening operations, as the weight of the new fill may cause a foundation failure (Article 1.2.3.2). The addition of seed and mulch immediately after completion of the new fill will reduce erosion of the slopes (Article 1.4.5.3). Such treatment may be required by environmental authorities.

Shoulder restoration work is done with off-track equipment supplied by either the railway company or an experienced contractor. The work is usually done at one time at all locations required along a particular section of track. If done by contract, bids for the work may be obtained on an agreed unit basis on which an experienced contractor can estimate, such as a cost per mile for each actual mile of work involved. If there is not sufficient fill available, the contractor may be required to provide suitable material as part of his contract.

1.4.3.3 Restoration of Earth Slopes

1.4.3.3.1 Basic Principles

An earth slope either above or below track which has failed so as to involve the safety of traffic must be repaired immediately. However, repairs should be carried out with the basic principles of slope stability in mind. Only in this way will the necessary immediate repairs tie in with long-term stability requirements. Neglect of this will lead to recurring instability or added costs in subsequent restoration work.

In an earth slope there are forces tending to cause sliding and forces resisting sliding. Forces causing sliding are gravity and water. Gravity acts through:

- the weight of earth in a slope,
- the weight of fills, stockpiles, structures, or traffic on a slope.
- vibrations from earthquakes or traffic.

Water acts through:

- the weight of water in a slope, particularly after rain or rapid draw-down of ponded water levels,

- the pressure of seepage water within the slope,
- the pressure of hydrostatic water in ground cracks in the upper part of of the slope,
- the softening of material in the slope,
- undercutting of the toe of the slope by erosion.

The resisting forces are made up of the strength of the soil along the sliding plane in the slope, and the weight of earth tending to be displaced at the toe of the slope. Slides occur when sliding forces increase or resisting forces decrease enough to cause movement. Sliding surfaces within the ground are often, although not always, shaped like the arc of a circle. During a slide, gravity carries material down at the top of the slope and out at the toe. In this way it reduces the sliding forces as well as increasing the resisting forces. The effectiveness of any form of slope stabilization will depend on how it affects these two forces.

1.4.3.3.2 Planning

Landslides occur most frequently at times of high groundwater or heavy rainfall. They seldom occur without advance cracking of the ground or other signs.

Planning for stabilization of an unstable slope should always start with a thorough inspection of the slope, if possible with an experienced geotechnical engineer, to find out what is happening. The inspection should extend up and down hill from the track for a distance well beyond the obvious signs of instability. A local failure will sometimes be part of a much larger movement going on in the general area.

Observations should be made of

- any recent excavation or filling,
- crack or bulges in the slope,
- water seeping into or out of the ground, wet areas,
- damming effects of frozen ground,
- direction, extent and depth of the movement, judging by the displacement of ground cracks, tracks, fence lines or leaning trees.

These observations should be supplemented by an analysis of the slope stability, based on drilling, soil sampling and testing whenever warranted by the importance of the problem and the time available.

1.4.3.3.3 Methods

Methods of restoring slope stability are chosen on the basis of site observations and analyses made, and the suitability, feasibility and economics of the various alternatives. It is sometimes possible to gain time to implement these measures by temporarily moving the track away from the unstable area.

Methods are reviewed in Table 1.4.4.

1.4.4 Widening of Cuts

1.4.4.1 Rock Cuts

Before excavation is planned, a survey should be made of the engineering characteristics of the exposed rock. Details of dip, joints, stratification, general competence and zones of weakness should be noted, along with the depth and type of overburden.

The new slope should be suited to the characteristics of the rock in which it is made so that minimum maintenance results. For example, steeply dipping rock should be cut at the angle of dip. See Article 1.2.2.1 for the procedure to arrive at

TABLE 1.4.4

METHODS FOR STABILIZING EARTH SLOPES

Method	*Remarks*
Reducing sliding forces	
1. Remove soil at top of slide area, flatten slope	Not always feasible.
2. Divert surface water flows	Use ditches, lined if necessary, or flumes.
3. Lower ground water level within sliding mass	Often applicable. For surface water use intercepting trenches, perforated pipes. For subsurface water use drilled-in horizontal or vertical drains.
4. Eliminate leakage from culverts	Not always feasible.
Increasing resisting forces	
5. Install pervious blanket	To keep slope surface material in place, preventing gullying and sloughing.
6. Construct berm over lower portion of slide area and beyond toe	Useful if feasible. Proportion berm on basis of stability analysis, ensure outer slope of berm is stable. Use free-draining material, or install granular blanket on slope under berm and provide through drainage. Compact berm material. If toe of slope is eroded by current or waves, install berm of riprap material.
7. Install wall or crib (see Chap. 8, Parts 5 and 6)	Must be founded on stable ground. May be expensive.
8. Install vertical piles along track	Only successful if sliding forces are small. Drive row of piles on both sides of track and tie rows together with cables or rods under track to form a crib.
Special methods	
9. Drill in anchors with beams and lagging	Must be conservatively designed by experienced engineer, especially if planned for permanent support.
10. Densify soil by vibration or compaction	Only possible with some granular soils. Specialized technique.
11. Grout, freeze, or apply electro-osmosis	Applicable only to special conditions. Very expensive. Experienced advice required.
12. Plant stabilizing vegetation on face of slope	Reduces water content of slope to shallow depths. Experienced advice required.

the best design slope. This may include benches, or a slope varying with the weathering resistance of the various rock layers. Drainage should be provided to reduce erosion and weathering.

Methods of treatment to stabilize the slope or protect the track from falling rocks may be considered as an alternative to widening an unsafe rock cut, or applied in conjunction with excavation of the new slope.

The method of blasting chosen is most important in reducing future rock scaling and other maintenance work required. The use of presplitting for producing a clean finished rock face should be considered (Article 1.2.2.1.5).

1.4.4.2 Earth Cuts

Cuts are widened in railway maintenance work to improve drainage, increase the stability of slopes, reduce difficulties in maintaining track or clearing snow, or sometimes to obtain borrow materials. Whatever the reason, it is important that a well drained stable cut is obtained in either earth or rock.

Methods of choosing safe slopes for cuts in various soils are given in Article 1.2.2.2. The reduction of seepage pressures within the slope by means of horizontal drains may be critical in cuts in water-bearing layers of soil. If slope stability analysis is not practicable, choice of a safe slope may sometimes be derived from observation of nearby cuts or natural slopes in similar soils, if care is taken to make allowance for differences in the level of the groundwater table, vegetation, and other influences on stability.

In making the cut, even temporary over-steepening (or undercutting) of potentially unstable slopes should be avoided, especially if the work is done during a wet season. Piles and lagging or crib walls can be used to support the back slope of the ditch if there is restricted right-of-way width to cut an entire bank back to a stable slope (and temporary stability of an undercut slope can be asssured). Drainage through the supporting structure should always be provided.

In sidehill cuts, material excavated from the upper ditch or slope should never be cast over on the downhill shoulder. This practice promotes failure of the downhill slope (Article 1.2.3.7). Such excavated material should be loaded and taken away.

The original vegetation will help to bind a slope together and provide subsurface drainage by transpiration. It should be preserved to the maximum extent possible on stable slopes. On freshly cut slopes, vegetation should be re-established to prevent erosion (Article 1.4.5). Surface drainage in a widened cut should be planned according to Article 1.2.4.2. A drainage system which is balanced to handle both slope and roadbed drainage throughout the cut is essential. Drainage of water from the top of the slope should be intercepted and brought around or down the slope without causing surface erosion.

1.4.5 DRAINAGE AND EROSION CONTROL

1.4.5.1 Ditches and Drains

Ditches of all types require periodic maintenance to preserve their function. Excess vegetation and deposited soil should be removed. Excessive scour must be corrected.

Less evident but also important is the periodic maintenance of subdrainage systems. Pipes and manholes should be periodically inspected and accumulations of sediment removed.

It is not generally realized that drilled-in horizontal drains also require maintenance. About once every 10 years, each pipe should be scoured to remove the accumulation of minerals tending to block the flow of water. Failure to do so will lead to a build-up of seepage pressures, resulting in slope instability which the drains were installed to relieve.

1.4.5.2 Erosion Control

Erosion of right-of-way slopes and ditches is caused by rainfall and frost, and affected by the steepness and height of slopes. Resistance to erosion depends on the strength and cohesion of the slope or ditch soil and the presence of protective cover such as vegetation.

Traditional practice has been to tolerate erosion if the track is not endangered and if the maintenance costs involved are not excessive. This point of view is too restricted today, as the results of downstream silting must also be considered. Erosion control where necessary on freshly cut slopes is good standard practice. After erosion develops and gullies are formed, protection is more difficult to arrange.

For all types of protection, a top ditch or other means to divert water from running over the top of slopes should be installed. Slopes should be restored to a uniform condition by filling gullies with tamped earth. Roadbed shoulders should be shaped to their design configuration to ensure uniform runoff.

There are several methods of erosion control, including variations of seeding and sodding, the use of layers of coarser materials, and filter cloths. These may be combined with flattening of slopes where warranted by soil conditions.

1.4.5.3 Seeding and Sodding

Steps in seeding and mulching eroded slopes consist of filling gullies and placing topsoil where required, applying fertilizer, seed and mulch, and maintaining and reseeding as necessary. Much detailed information can be obtained from the standards and specifications used by local highway authorities. Suitable seed mixtures and fertilizers for particular locations can be recommended by agricultural bureaus. Grasses or ground covers can be used to control erosion. However, ground covers can be killed by chemicals used to control vegetation along the right-of-way.

The application of seed and fertilizer is done on flat areas and moderate slopes with a seed drill, and on steep slopes with a hydroseeder. A mulch spreader is used to apply straw tacked with asphalt. Although this mechanical equipment is efficient and economical to use, small eroded areas can commonly be prepared and treated by hand, with substantial benefits. Grass should be cut at least once to thicken the growth.

Where active erosion of young growth may occur, jute matting can be used with seeding, giving good protection against erosion for at least two years. Matting is effective on slopes up to 15 or 20%. Seed and fertilizer is applied both under and over the jute, without mulch. The matting should be applied according to specified procedures.

Sod is costly and usually only used on areas where immediate vegetation coverage is required for aesthetic reasons. Where necessary to prevent slippage on slopes, sod should be pegged in place. Use of light wire netting over the sod, through which the pegs are driven, will assist in this.

1.5.5.4 Filter Layers

Earth slopes can also be protected against erosion by a layer of coarser material. In such cases it is essential to divert concentrated flows of water from the top of the slope and to fill gullies. Filling gullies with coarse material will not in itself prevent further erosion.

The function and design of graded filter layers is given in Article 1.2.5.3 and Fig. 1.2.6. This design method is used when water seepage from pervious layers in the slope causes erosion. The filter layer is designed to keep the underlying soil in place while at the same time carrying flow from both seepage and rainfall without eroding itself. The thickness of the layer required depends on the intensity of rainfall. A filter layer must be carefully designed and installed. However, it will prevent erosion under conditions too severe for seeding or sodding to survive.

1.4.5.5 Filter Cloths

The function of a filter layer in preventing erosion on an earth slope can also be performed by a filter cloth (Ref. 4). These porous plastic membranes are available as woven cloth or as thin fibrous mats. In either form they are designed to be fine enough to hold the slope soil material in place, but porous enough to allow passage of seepage water to prevent uplift pressure.

The performance of filter cloths is often superior to that of filter layers as they have a built-in filtering capability which does not depend on field workmanship. Detailed installation procedures are available from manufacturers. Generally, the slope to be protected must be uniform and gullies and holes filled. The cloth is spread loosely on the slope, with overlapping sheets pinned in place. A layer of random gravel or crushed stone is placed immediately on top of the cloth to keep it in place, working from the base of slope upward. This material must be coarse enough to withstand erosion in itself.

1.4.6 METHODS OF OPENING SNOW BLOCKADE

1.4.6.1 General

Keeping a railway line open in territory subject to heavy snow requires watchfulness, orderliness and forethought. In the fall of the year all snow equipment and accessories should be tested and made ready for emergency use. A general program should be formulated for stationing snow-fighting equipment at vantage points, outlining a general supervisory plan, and determining methods by which men are to be secured, protected from hazards attending snow storms, fed and relieved.

Where such reports are considered helpful, metereological information should be made available for general and division officers, and local officers should be kept well informed of the progress of approaching storms.

It is desirable to keep ahead of storms and not let the line become blocked. In some areas best results are obtained when snow plows are started from terminals before the storm actually breaks and, in severe storms, additional plows dispatched at such intervals as will preclude the formation of snow banks that cannot be moved with plows. A follow-up locomotive to pull out the plow or its engine, or both, if they get stalled or derailed, is good practice when conditions warrant. Prompt clearance of cuts before further snow or wind storms is quite necessary. It is the following storms which generally cause real trouble.

During severe storms, if there is difficulty in keeping the line open, consideration should be given to reducing tonnage, double heading or the abandonment of trains and curtailment or complete stopping of yard switching until the storm abates and the line is opened. Stalled trains and dead locomotives add much expense, anxiety and hazard to the work of moving snow and delay the opening of blockades.

No definite rule can be established for the use of flangers or plows. Much depends on the moisture content of the snow, the formation of drifts, and on the available clear space for snow disposal. However, the following suggestions are made as recommended practice:

1.4.6.2 On Line

Flangers should be used for the removal of snow where the depth is less than 6 in over the top of the rail. Flanging of tracks is greatly expedited if the flanger is equipped with scoops for each direction, which allow flangeways to be cleared in either direction without turning the flanger. The scoops must in all cases be equipped with lowering and raising device operated from inside the car. A flanger may frequently be used to good advantage by attaching it to the rear of a freight train and thus avoid using an extra train and crew.

The wedge or push plow placed on the pilot of the locomotive is useful for occasional light drifts of up to 2 or 3 ft over the top of the rail, if state laws permit such operation.

The larger wedge or push plow should be used for removing snow up to 6 or 8 ft deep which cannot be removed by flangers or push plows on locomotive pilots. The effectiveness of these plows is greatly increased if they are equipped with adjustable side wings, which can be used for widening the opening. These plows should be equipped with a coupler on front as well as rear to expedite the switching of cars off of siding or yard tracks which must be cleared of snow. Means of communication by telephone or signals between crew and plow operator expedite this operation.

Great care must be exercised in the use of plows placed on the front of loaded ballast or gondola cars to prevent the cutting edge of plow from riding on the rail and catching at frogs, switches and crossing plank due to the weight of the snow. This can be prevented by a narrow casting placed under the plow near the cutting edge so as to ride on the rail and keep the plow up. Special consideration must be given the designating and placing of this casting if self-guarded frogs are to be encountered. There are combined flangers and plows so designed that this difficulty does not obtain.

Care must be taken when entering oblique snow drifts which plows will not strike squarely, as such conditions sometimes result in the plow turning over. If the face of drift is frozen over the rails, it should be broken down or "faced" so that the plow will engage the snow and not ride on top of it. If the plow has been stuck and pulled back, the snow may have been compacted to such an extent that it should be broken down before making another charge and possibly causing serious damage to the plow from impact with the solid snow.

Spreaders or spreader ditchers with a plow-shaped front make excellent snow movers. The spreader wings can be used to good advantage to widen the cut after it is opened up. Many of these ditchers are equipped with steel teeth set under the front edge of the plow, which are very effective in cutting up ice which may have formed between and over the rails.

Ice cutter cars have been used with great effectiveness for loosening hard snow and ice which form in the tracks, especially in yards, and on occasions in many miles of tracks. These cars are essentially box cars with end lookout windows, and with compressed air equipment by means of which a lever may be moved to raise and lower a plow or V-shaped steel plate, 1 in thick, 6 in wide, and about

4 ft 9 in long, placed below the center of the car on edge and between the running rails. To this steel plate, 4 in apart and extending 6 in below its lower edge, are bolted tire-steel teeth with points inclined slightly forward. Extra teeth are carried in the car. The cutter must, of course, be raised at turnouts and crossings.

Rotary snow plows are necessary for the quick removal of snow where the snowfall has filled deep cuts, which cannot be removed with push plow. Attempts to use them in shallow drifts not deep enough for reasonably full contact of the wheel may cause the wheel to race under the light load and damage the machinery.

When operating flangers and plows over the line, the problem of keeping ice and snow out of guard rails, frogs and switches is important, particularly in locations which are difficult for section men to get to in severe storms. Carbide carried on the plow and placed on the ice will in a short time get sufficient moisture to form gas, which can be ignited; the heat generated will melt the ice. Casing head gasoline, or hydrocarbon might also be sprinkled over such places and ignited. Salt can be used also, except in electrified, automatic signal, or train-control territory.

I.4.6.3 In Yards and Terminals

The method for removal of snow from yards and terminals depends upon the physical layout, the density of traffic, and the amount of snow. If snow is not very deep, it is best not to remove it from the tracks, except to make flangeways by hand shoveling, or with flangers if traffic will permit, and clean out switches by hand or snow melters. The use of the latter requires good drainage to carry away melted snow as it may freeze and cause more trouble than the snow, or heat must be great enough to evaporate the water. Frequently switch engines are equipped with a perforated pipe laid across the track under the pilot, through which steam is blown to clean away snow. If traffic is not too dense, this may be successful, but in dense traffic districts another engine added is often a nuisance. Then, too, if not judiciously used, it may be simply a case of blowing snow back over places already clean. Casing head gasoline and hydrocarbon sprinkled over snow and ignited is also used. Salt should not be used in electrified, automatic signal or train-control districts and should be used in other districts only during that portion of winter when snow melts during the daytime and freezes at night.

In clearing yard tracks of heavier falls of snow, it is well first to pull cars off of four tracks; then run a plow down one track and follow with a spreader, pushing the snow clear of adjacent tracks; then run the spreader down the cleared tracks, repeating the operation until the snow is piled too high for further piling. Then start on the other side of the pile and repeat. In some instances, where the yard is not too wide and the snow not too heavy, the entire yard may be cleared with the spreader; thus picking up the snow is avoided. Where this cannot be done, the piles of snow must be left to melt or be loaded onto cars either by hand or machinery. A snow melter consisting of a rotary-type plow which picks up the snow and deposits it in a melting bath of steam has been used to advantage in some localities.

In cleaning snow off station platforms, where snowfall is light, hand methods are probably the cheapest. Small steel or wooden hand push plows are effective. Use should be made of baggage trucks, on which to load and carry away snow. Snow should not be placed on tracks, as passing trains may throw it over passengers waiting on platforms. Hard-operated power snow plows or farm tractor-type plows are useful for platform cleaning. A supply of sand should be on hand at stations to scatter over platforms in sleeting and freezing weather.

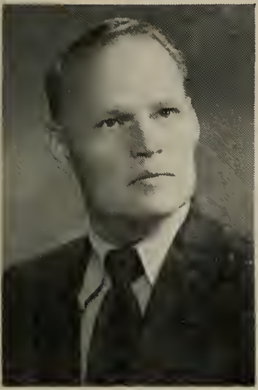
At team yards snow can be pushed to the center or side of driveway with plows placed on automobile trucks or tractors. The snow may be left to melt or loaded onto trucks or cars by hand or machinery. Front-end loaders attached to tractors are useful in this operation.

Snow blowers, revolving brooms attached to small tractors, and flangeway cleaners attached to motor cars are other devices that have been found useful in cleaning crossings, yard leads, etc.

REFERENCES

1. Ayers, D. J., Unstable track formations respond to bituminous spray treatment, *Railway Gazette International,* v. 128, n. 7, July 1972, p. 263–264.
2. To be presented.
3. To be presented AREA Annual Technical Conference, March 1975.
4. Calhoun, C. C., and W. E. Strohm, Jr., Performance of plastic filter cloths as a replacement for granular filter materials, Highway Research Record No. 373, 1971, Washington, D. C.

Report of Committee 6—Buildings



W. C. Sturm, *Chairman*
E. P. Bohn,
Vice Chairman
O. C. Denz, *Secretary*

T. H. Seep
J. G. Robertson
J. A. Comeau
R. Hale
W. C. Humphreys
W. F. Armstrong
F. R. Bartlett
D. A. Bessey
G. J. Bleul
W. L. Burgess
A. C. Cayou
G. J. Chamraz
F. D. Day
C. M. Diehl
G. W. Fabrin
C. S. Graves (E)
A. R. Gualtieri
J. W. Hayes
H. R. Helker
S. B. Holt
K. E. Hornung
W. G. Harding (E)
C. Madeley
R. J. Martens
R. W. Milbauer
L. S. Newman
J. Norman
L. A. Palagi
T. F. Peel
P. W. Peterson
R. E. Phillips
R. D. Powrie
R. F. Roberts
J. H. Rump
J. B. Schaub (E)
H. A. Shannon
J. S. Smith
S. G. Urban
W. M. Wehner
O. G. Wilbur (E)*
T. S. Williams (E)
Committee

---

* Died September 20, 1974.

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Manual recommendations submitted for adoption were printed in Part 1 of Bulletin 650, November–December 1974. Included were additional information in Part 2 on conference rooms and three new parts: Part 6—Locomotive Sanding Facilities, Part 7—Pre-Engineered Metal Buildings, and Part 8—Design Criteria For Railway Passenger Stations. Revised and/or obsolete Parts 20, 23, 25, 26 and 27 were recommended to be deleted. Adoption of these recommendations will complete the task of converting Chapter 6 to the decimal format.

1. Maintenance of Way Equipment Repair Shops.
Preliminary and final drafts of the report have been reviewed. It is anticipated that this material will be forwarded to Committee members for ballot vote for inclusion in the Manual in the early part of 1975.

2. Portable Crew Housing.
Final report, submitted as information .... page 301

3. Computer Room Design.
Final report, submitted as information .... page 310

4. Elevated Yard Office Buildings.
   A preliminary report was reviewed at the summer meeting and a final report is being prepared which will be reviewed. It is anticipated that this material will be forwarded to committee members for letter ballot vote for inclusion in the Manual during 1975.

THE COMMITTEE ON BUILDINGS,
WALTER CARSON STURM, *Chairman.*

Otis Gray Wilbur
1892-1974

Otis Gray Wilbur, retired assistant engineer of bridges and buildings for the Baltimore & Ohio Railroad, passed away at Fort Lauderdale, Florida, on September 20, 1974.

Born in Baltimore, Maryland, May 29, 1892, Mr. Wilbur graduated from Baltimore Polytechnic Institute in Civil Engineering in 1911. He joined the B&O in 1911 holding various engineering positions, retiring from railway service in 1959. He worked on many important engineering projects including the design of the largest waterfront terminal in the port of Baltimore and the B&O Chelsea Freight Station in New York City.

Mr. Wilbur joined the AREA in 1921 and became a Life Member in 1956. He was a member of Committee 6 continuously since 1923, having been elected Member Emeritus in 1960. He was vice chairman, 1934–1936, and chairman 1937–1939. He was also a member of the Committee on Waterproofing from 1937 to 1943. He was a member of the American Society for Testing and Materials, the Engineers Club of Baltimore and the Building Congress and Exchange of Baltimore. He was the only railroad representative of the American Lumber Standards Committee of the United States Department of Commerce and was listed in Who's Who in Railroading.

He was former Master of Pythagoras Lodge of the Masonic Order and a member of the Scottish Rite and Boumi Temple of Baltimore. Mr. Wilbur was also Grand Inspector and Senior Grand Warden of the Lodge of Maryland.

He was a former trustee and chairman of St. Marks United Methodist Church, Baltimore where he was superintendent of the Sunday School for 12 years. After retirement to Fort Lauderdale, he served as treasurer of Christ United Methodist Church for eight years and served on the Board of Trustees of that Church.

Mr. Wilbur is survived by his wife, Helen White Wilbur; two sons, Otis Gray Wilbur, Jr. of Fort Lauderdale and Dr. Holmes Otis Wilbur of Muskegon, Michigan; a daughter, Mrs. Robert A. (Dorothy) Amos of Towson, Maryland; and five grandchildren.

Report on Assignment 2

Portable Crew Housing

J. A. Comeau *(chairman, subcommittee),* P. W. Peterson, R. D. Powrie, J. G. Robertson, J. H. Rump.

Your committee submits the following report, as information, on portable crew housing units for installation on open-deck flat cars, inviting comments and criticism thereon.

General Statement

(a) Railroads with the problem of remote crew housing for system maintenance and work forces are faced with new and stringent state law requirements. At present accommodations for these work crews range from converted box cars and passenger equipment to highway type trailers, bunkhouses and a variety of wayside buildings. The cost of converting box cars and passenger equipment to dormitory units that will measure up to today's standards for industrial type housing is excessive.

(b) Recently some railroads have explored the use of mobile housing units mounted on the open deck of a flat car, in some instances converted from a standard box car. These units are designed specifically for railroad service and provide an acceptable standard of living accommodation for work crews.

(c) Each unit is designed to be mounted on a standard 40-ft flat car or mounted in tandem on 85-ft flat cars. They can be put together in a train consist in any combination that may be required to achieve full flexibility in meeting the housing needs of work crews of different sizes and types.

Unit Flexibility

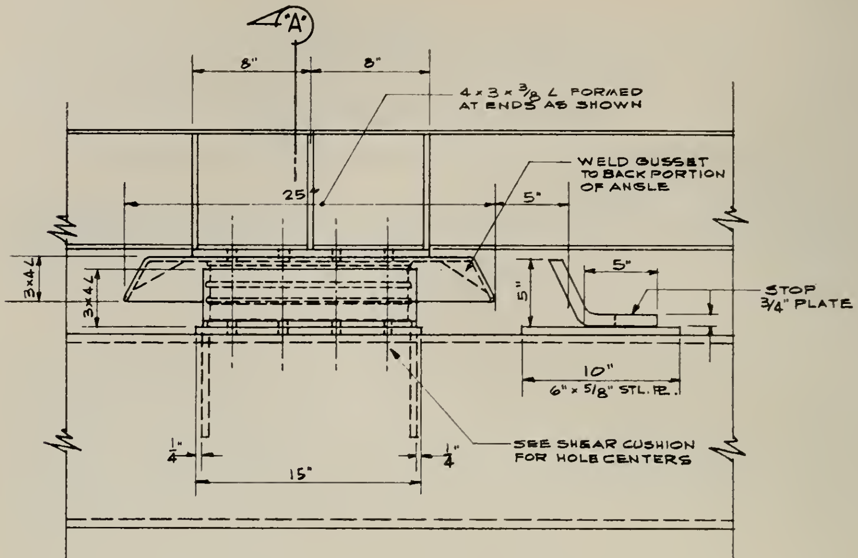
In addition to the basic requirements, the completely functional unit should be capable of being lifted from the flat car and located on timber blocking type foundations or on a steel chassis for highway travel. The units are then adaptable for use as a temporary construction camp where siding limitations require that the units be unloaded to provide living accommodation for the work crews, on a specific construction site.

Cyclic Loading

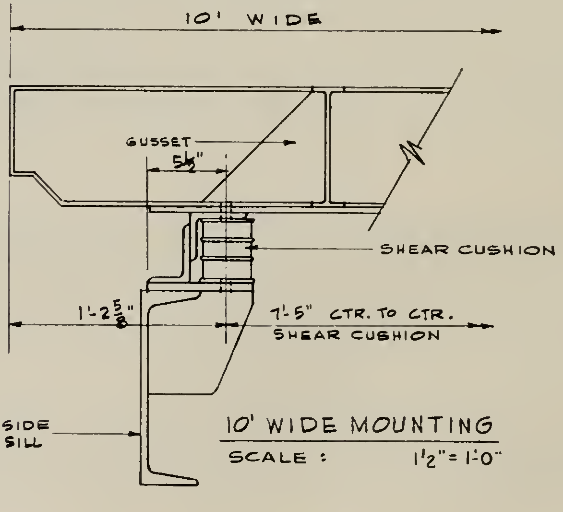
Load frequencies in the range of 1 to 5 cps will be encountered in rail travel. Equipment, material and fastenings should be designed to minimize the transmission of loads in this range.

Unit Mounting

Provision should be made to mount the units on the flat car in a secure manner, to resist the specified loads. A typical shear cushion type of mounting is shown in Figs. 1 and 1A. Provision should also be made to protect the exterior siding from damage when the unit is handled. Metal angles should be provided to protect the bottom side plates from crushing when lifting on or from the flat car, using cables or belts.

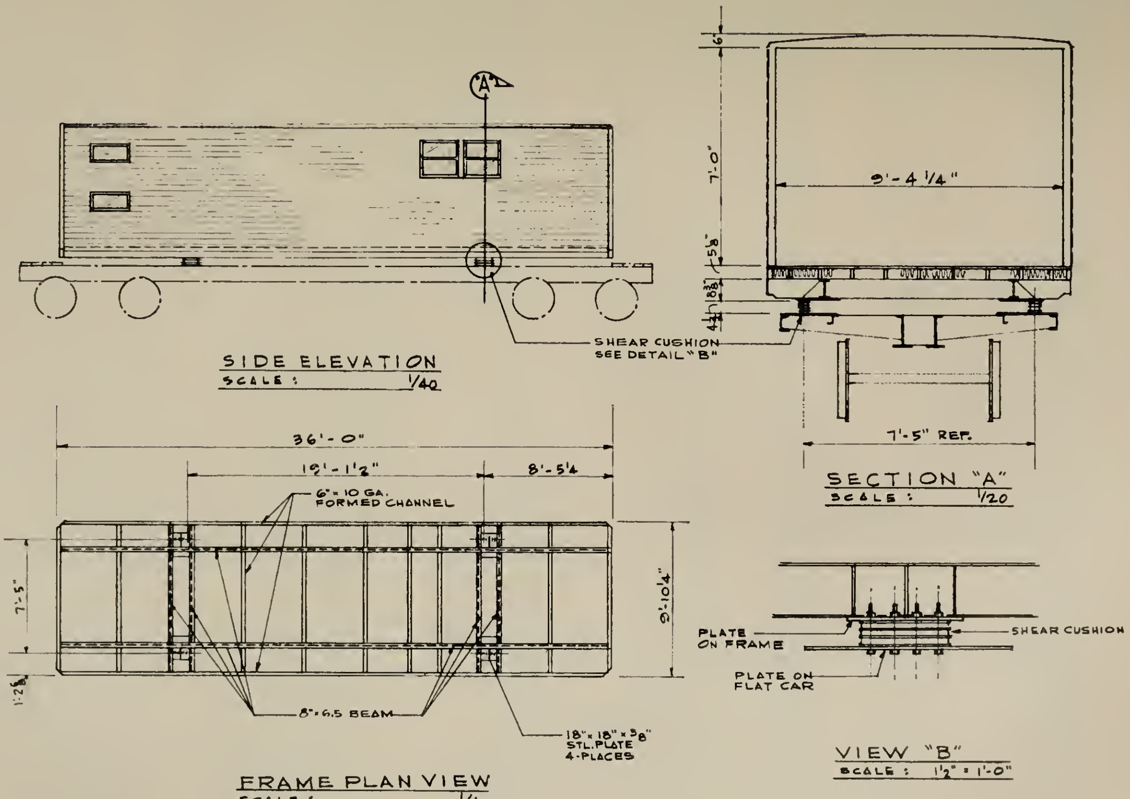

"A"
8"
8"
4 × 3 × 3/8 ∠ FORMED AT ENDS AS SHOWN
WELD GUSSET TO BACK PORTION OF ANGLE
25"
5"
5"
5"
3×4∠
3×4∠
STOP 3/4" PLATE
10"
6" × 5/8" STL. PL.
SEE SHEAR CUSHION FOR HOLE CENTERS
1/4"
1/4"
15"

SIDE ELEVATION - STOP ASS'Y.
SCALE : 1½" = 1'-0"



10' WIDE MOUNTING
SCALE : 1½" = 1'-0"

FIG. 1



SIDE ELEVATION
SCALE : 1/40

SECTION "A"
SCALE : 1/20

FRAME PLAN VIEW
SCALE : 1/40

VIEW "B"
SCALE : 1½" = 1'-0"

FIG. 1A

EQUIPMENT MOUNTING

All equipment tie-downs should be provided with adequate support backing in floors and walls to insure resistance to specified forces. This includes water storage tanks, heaters, furnaces, toilet partitions, etc.

GENERAL DESIGN CRITERIA

Floor Live Loads:

Living quarters —40 psf
Wash car/recreation—50 psf

Floor load—Mechanical Equipment Area:

The floor supporting mechanical equipment shall be designed for a uniformly distributed load.

Wind Loading:

External walls and roof should be designed to withstand a steady wind force equivalent to 100 mph.

Roof Loading:

Snow load—40 psf

Dynamic Loadings (Rail Transport):

The longitudinal and vertical acceleration to be designed for should be as much as 10 G's, with coupler forces in excess of 750,000 lb and lateral forces up to 1 G.

CONSTRUCTION

(a) Units are factory pre-built, specifically designed to provide a structurally sound facility for flat-car mounting.

(b) A substructure of steel or wood should be designed to withstand the heavy service requirements of rail transportation.

(c) Wall and roof assemblies are primarily steel or wood framed, insulated, throughout.

(d) The floor assembly usually consists of wood joists, plywood sub-floor, particle board underlayment and commercial-grade floor tile.

(e) Interior wall surface materials should be selected for ease of cleaning, particularly in the kitchen and washroom areas.

(f) The exterior of the unit is covered with baked-on pre-finished aluminum sheathing.

(g) Windows of pivoted or sliding type, aluminum frame, double-strength glass, complete with storm sash and screens are recommended.

(h) Entrance doors of pre-finished aluminum construction, continuous piano hinge, weather-seal, and lock, should be provided.

PLUMBING

(a) Units should not depend on stand-by facilities for fresh water supply or drainage; however, switch-over valves for local water main supply should be provided.

(b) Provision for piping water from a fresh water storage tank through each unit of the crew housing consist should be designed, in order to provide water for lavatories, showers, drinking fountains, and kitchen requirements. Waste water should be chemically treated and piped to a waste water storage tank for disposal, in accordance with environmental regulations.

(c) Pressurized water system, designed to comply with National Building Code, complete with air compressor, pump, and water heater should be provided. Internal piping lines should be protected from freezing by wrapping with electric thermostatically controlled heat tape.

HEATING

(a) Thermostatically controlled forced air, oil or propane gas furnaces with underfloor duct systems should be designed for each crew housing unit to maintain interior comfort under sub-zero conditions.

(b) All furnaces should be equipped to provide summer circulation of air.

(c) Forced air registers should be wall mounted in preference to floor locations.

(d) Fuel oil storage tanks or propane bottles, racks and regulators should be provided and securely anchored for transit.

ELECTRICAL

(a) Electric power for the crew housing train is furnished by generators designed in pairs; either generator should be capable of handling the total connected load.

(b) The service line through each unit should be of capacity to limit the voltage drop to 3%.

(c) Receptacle jumper connection should be of design and type to provide freeze control to each unit while in transit.

(d) Lighting between cars and all corridors should be provided.

(e) All lenses on light fixtures should be impact resistant, unbreakable type.

(f) All wiring should be designed and installed in accordance with the National Electrical Code.

(g) For the larger crew consists the railroad should provide a 15-kw diesel generator unit. Smaller generators are provided for the self-contained units.

EQUIPMENT AND FACILITIES

(a) Flat-car crew housing should be designed to provide: sleeping, washing, toilet, kitchen, dining and recreation areas.

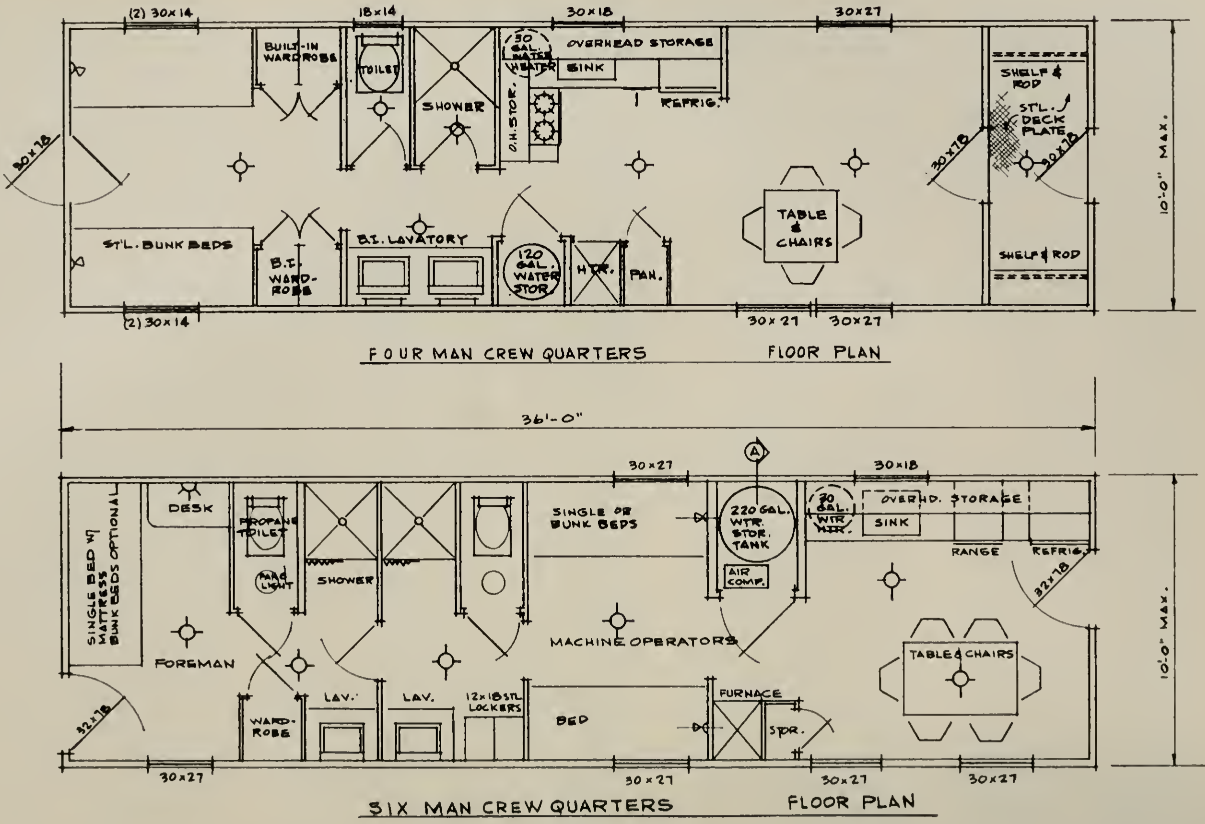
(b) Provision should be made for dormitory type or individual sleeping rooms, as local conditions may require. They should be ventilated and equipped with beds, chairs and lockers.

(c) Wash rooms should be equipped with showers, wash basins, mirrors and the usual accessories provided in a modern lavatory.

(d) Kitchen and dining area should include: sink, electric or propane gas refrigerator and cooking range, sanitary counter top and back splash, storage areas, power exhaust fan, range hood, dining table, and chairs. This equipment should be durable and sanitary.

(e) The dining area can be utilized as a lounge, reading room or for television viewing.

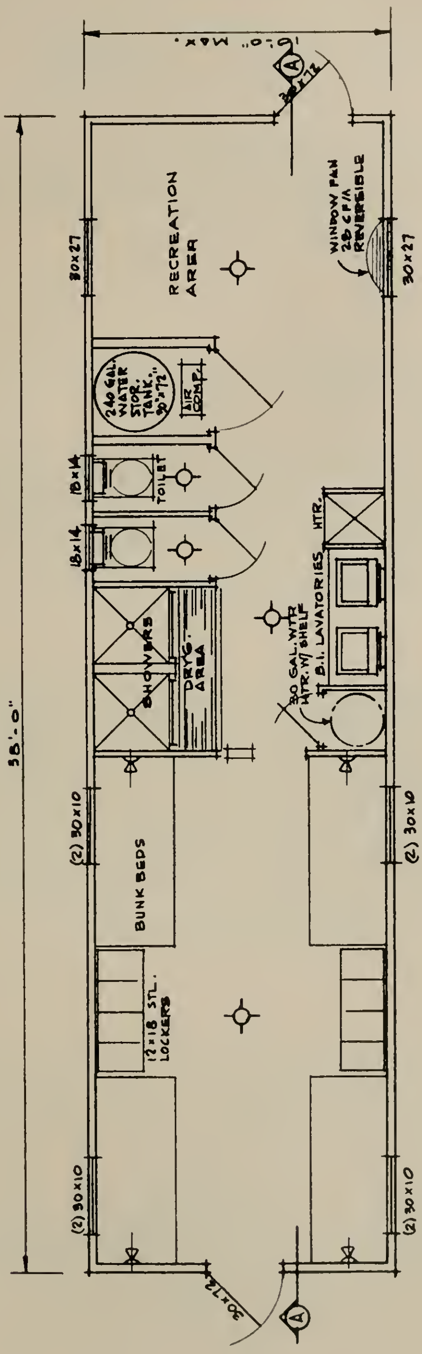
(Text continued on page 310)



FOUR MAN CREW QUARTERS FLOOR PLAN

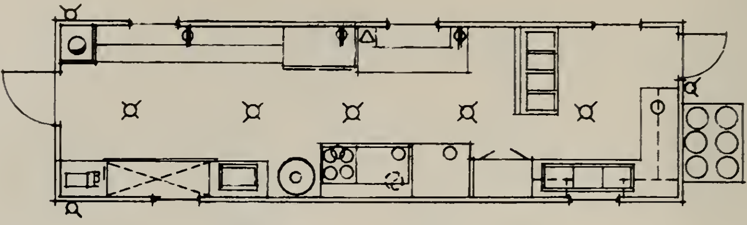
SIX MAN CREW QUARTERS FLOOR PLAN

Fig. 2

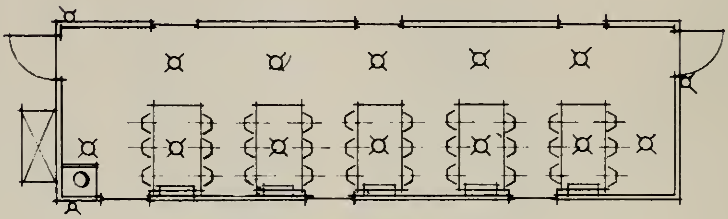


FOUR MAN TO EIGHT MAN SLEEPER FLOOR PLAN

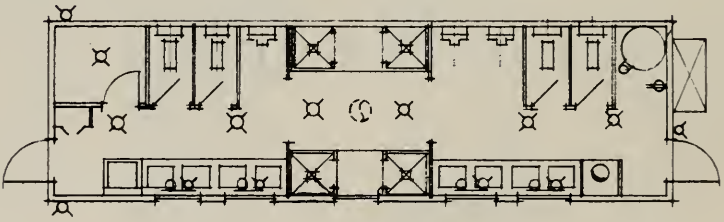
Fig. 3



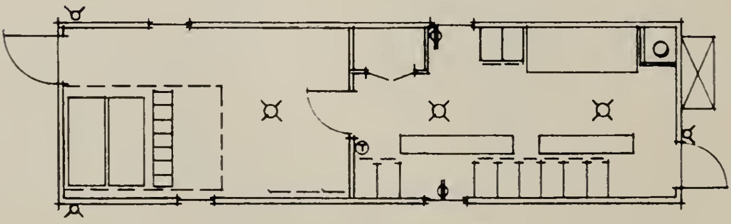
10'x 34' KITCHEN



10'×34' 30-MAN DINER

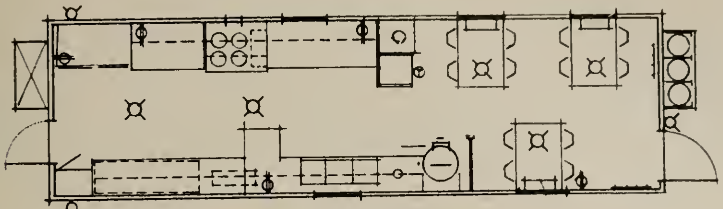


10'×34' 100 MAN WASHCAR

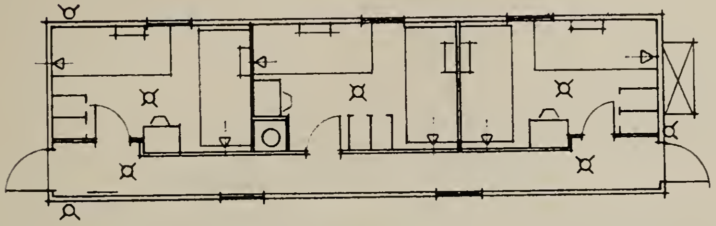


10'×34' TOOL GENERATOR

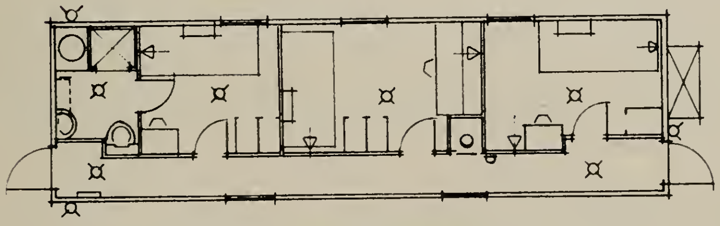
Fig. 4



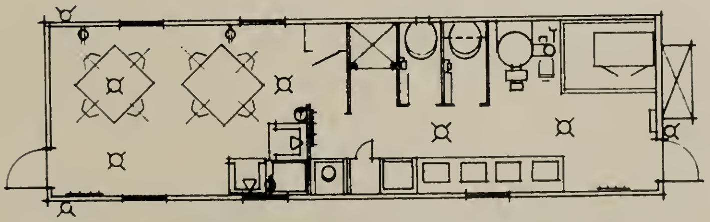
10' × 34' KITCHEN DINER



10' × 34' 6 MAN SLEEPER



10' × 34' COOK, FOREMAN, & ASSISTANT FOREMAN



10'×34' RECREATION WASHER

Fig. 5

To meet the requirements of small work crews the self-contained units shown in Figs. 2 and 3 provide the necessary facilities to comfortably accommodate 4, 6 or 8 men.

A combination of the different unit types as shown in Figs. 4 and 5 offer full flexibility in meeting the requirements of larger crews of as many as 100 men or more. They can be put together in a train consist as required to provide good living accommodations.

SUMMARY

For the railroad that must rely on its own equipment for housing and feeding its road crews, mobile housing, designed for rail service provides a solution to the problem of improving the living environment of away from home work crews.

Report on Assignment 3

Computer Room Design

RICHARD HALE *(chairman, subcommittee)*, G. J. BLEUL, G. J. CHAMRAZ, A. R. GUALTIERI, W. C. HUMPHREYS, R. J. MARTENS, H. A. SHANNON, JR., J. S. SMITH.

Your committee submits the following report as information. Comments and criticism thereon are invited.

The difficulties of computer room design are many and varied. This report will attempt to point out some of the problems, and show what can be done to alleviate or eliminate them. Although some occurrences, such as events of nature, cannot be eliminated, computer rooms can be designed so that these occurrences when they do happen will not cause as much damage, down time, or physical or personal loss, as they would had there been no real planning or careful consideration given the problems.

Space requirements for computer rooms will naturally vary with the number and types of operations. The number of machines and space requirements should be determined by conferences with the personnel that will make use of the system, the manufacturer's representative and the person who has the responsibility for the design of the project.

The location of the computer room within the structure will be determined by several factors. The primary, most vital factor in this determination is security, which will be discussed at length later in this report. Of secondary importance is the movement of information, from the initial input, (punch cards, etc.), to the final use (printouts, readers, etc.). This could take the form of direct relationships in the planning, or mechanical means of conveying the data through the processing procedures.

Any raised floor with total access would be classified as a computer floor, with no limitation as to the materials or method of construction. However, common sense and most fire prevention regulations and authorities would rule out combustible materials. There are several types of commercial computer (access) floors available. The most common size for the removable panels is 24 inches square. They are made of cast aluminum or pressed steel, although the cast aluminum panel is falling into obsolescence because of distortion over a period of time due to the concentrated loads of the equipment. These panels are available in a high-pressure, laminate surface of anti-static vinyl tile, which is less expensive but requires more maintenance; and carpet, which is most expensive, (having good sound control) but has dust-catching seams, as the carpet is wrapped around the edge of each panel. The manufacturers all furnish a tool for removal of these panels, the required number to be specified. All manufacturers furnish (quantity as specified) vented panels, with and without dampers, the dampers being used where air volume regulation is required. Air distribution will be discussed later in this report.

The supports for these panels (pedestals), are adjustable, within limits, to compensate for normal irregularities in the underfloor. There are two systems available—without lateral supports, and with lateral supports. The system without lateral supports is much more flexible, in that it allows several adjacent panels to be removed. This system can be used in most installations, although it does limit the depth of the underfloor space. The system using the lateral supports does not limit the depth of the underfloor space and is inherently stronger. As in the non-supported system, several adjacent panels may also be removed, but it is lacking the free area of the non-supported system due to the lateral supports. Both systems, supported and non-supported, have pedestals at each corner of the panels.

Community, county, state and federal regulations must be investigated by the designer to determine which is the more strict with respect to fire hazard, electrical installations, and personnel safety in general. Some of the design considerations which will be affected by these regulations are: use of the underfloor space as a plenum; protection of electrical wiring and receptacles in the plenum; methods and extent of electrical grounding of the floor; emergency switches at each exit which kill all power in the computer room, including air conditioning equipment and/or power-actuated fire dampers on both supply and return ducts; and lateral stability of the floor system. When remodeling, care should be taken to thoroughly check the floor loading to be sure the loading is sufficient to handle loads of moving the machinery (safes, etc.).

There are many types of fire-extinguishing systems, and each has its own place. The most basic is an adequate number of the proper type of hand fire extinguishers well-placed about the computer area. Computer personnel must be trained in the proper use of these extinguishers in order for them to be effective. They should also be trained in other emergency procedures. Hand extinguishers should be used with all systems.

There are three basic types of fire sprinkler systems presently used in computer room installations. They use as the medium either water, carbon dioxide, or a proprietary product. The least expensive of the sprinkler systems uses water as the medium. This can be used in the computer room proper, and in paper storage areas. It is not the most desirable, as the computers must be "dried out" before they can be used, and exposed tapes will be damaged.

The second system uses carbon dioxide as the medium. This is a good system, but it involves some danger to personnel, because when carbon dioxide is released in an area, it displaces the oxygen in the area. The best place for this system is the tape vault and storage areas, as it will not damage tapes. There have been cases, however, where the fire has been rekindled when oxygen is allowed to re-enter.

The third system, and the most expensive, is the proprietary product. It is a retardant catalyst, preventing the molecules from combining to produce combustion.

Therefore, it will not support combustion. This system can be used in the computer room with much less danger to employees than the carbon dioxide system, and in support areas with no damage to tapes and supplies.

Tapes that are stored in the same location as the computer room should be stored in a vault. This vault should have a four-hour rating and should have either the carbon dioxide or the proprietary product fire extinguishing system with a separate detection and alarm system.

These protective measures for the computer complex are more for external fires, i.e., fires that start outside the area, preventing them from spreading into the complex.

In all fire-extinguishing systems, it is essential to have an early warning detection and alarm system. It is recommended that the alarm system be a combination of sound and flashing lights, the latter to safeguard personnel that may be working near noisy machinery. There are three basic types of sensors that are in use today. The first is called the Absolute Temperature Detector. This will set the system into operation when a certain temperature is reached. A good use for this type of detector would be in the main computer room where a small fire could be handled with hand extinguishers. The second sensor is capable of detecting a pre-determined rise in temperature. The gaseous products of combustion are detected by the third type of sensor. The last two should be used in storage areas and the tape vault where there will be longer periods of time when no personnel will be present.

There are several systems of air conditioning for computer rooms. The main three functions of these systems are: cooling, heating, and humidifying. Some installations are split, one system for room comfort and one for the machines. This installation is most suitable for direct air flow to the machines. Some manufacturers, however, will not allow direct air supply under the machines, as condensation can form. If this is the case, there is no need for a split system as all air can be supplied to the underfloor area, directed next to the machines and around the room through the perforated floor panels. Another application for the split system occurs when vertical banks of computers are used. The conditioned air is fed into a built-up plenum behind the equipment. Two rows of computers can be supplied by the same plenum, which also acts as an area for repair of the equipment. The return air in all cases is placed in the ceiling.

The designer must consider sound control in the planning of the computer complex. This can be accomplished by an acoustical ceiling, carpet on the walls, and sound baffles around the noisiest equipment.

As stated earlier in this report, computer room security is undoubtedly the most important phase of the design problem. The worst threats are posed by fire, water, and malicious acts of people. Some of these threats have occurred in the past. For example: the 1959 Pentagon fire, and a fire at an IBM installation that was apparently caused by arson. Water damage to computer centers has occurred from hurricanes, floods, activities of firemen on upper floors, broken pipes, sprinklers, sewer lines, leakage in the computer's water cooling system and loss of power (which can be overcome with a combination of batteries for uninterrupted power and a generator for extended power failures). In the Pentagon fire, the damage caused by water was much worse than that caused by the fire itself. There have been many cases of sabotage by striking employees and recently terminated employees. The computer is a symbol of mechanization and automation and, as such, is a target for dissident members of society. Other events which have affected computer centers adversely are: explosions, earthquakes, tornadoes, aircraft crashes, lightning and foreign materials introduced into the air-conditioning system both accidentally and on purpose.

There is no totally secure computer installation. This is not technically nor economically feasible. Steps may be taken to reduce the risk as follows:

1. *Physical Location*

A wise choice will greatly reduce many hazards. Computers have been located at airports, over garages, boilers, paint shops, in old wooden warehouses, basements, store fronts, on campuses, in earthquake-prone areas, in heavy-traffic areas of office buildings, and other such choice sites. If a vulnerable site must continue for the present, steps can still be taken to reduce the vulnerability; for example, where water damage is a high risk, store media as high as possible; provide drains, pumps, emergency power for pumps and fitted plastic covers for equipment; and seal utility outlets.

2. *Physical Access Control*

This has received considerable attention at many installations, but there are serious deficiencies and token protection. Badges are not checked carefully; locks are taped open or released without adequate investigation of the visitor; security is lax at night or weekends; the facility is wide open and unsupervised during the weekly heavy cleaning period, etc. *Nobody* and *nothing* should be permitted to enter the computer room unless they need to be there *then*. All legitimate visitors should be accompanied by a staff member. There should be as few windows and doors as feasible. Normal access should be via one tightly controlled entry point; other doors should have alarm devices on them. A wide range of devices are available for access control, including use of a computer for this purpose. The key defense, however, should be an alert computer staff which will immediately challenge all strangers who gain access by whatever means. Physical access control should include bomb protection against packages and mail which should be opened outside the computer center. Control of access to remote terminals is increasing as a problem.

The degree of security can vary widely depending on the type of computer installation. For external security, starting with the least effective and least expensive, there are: a simple key-locked door; locked door with an intercom system; a locked door with closed circuit television; and double-locked doors forming a vestibule or body lock with TV monitor, making it impossible for a person to leave without being released. Card keys may be substituted for keyed doors in all cases above. A microwave burglar alarm system should be installed in all but 24 hour complexes with a line to the local police station. All repair men and maintenance workers should be checked out to authenticate employment. There are very few safeguards against internal sabotage. A check should be made for magnets, which will destroy a running tape. The supervisor should have the only key to the tape vault to prevent the switching of labels on the tape canisters by a disgruntled employee.

3. *Fire Protection*

This has been thoroughly discussed previously.

4. *Media Protection*

A misconception should first be cleared up. There is no precise figure, such as 150°F, below which magnetic media are safe or above which they are destroyed.

However, the degree of humidity is quite significant. High humidity can cause serious media deterioration without great temperature elevation and, conversely, at low humidity levels, considerable temperature elevation may not result in serious damage. Up to about 125–130°F at normal humidity levels in data centers, few problems are encountered. As the temperature is raised, a gradual increase in the error rate on reading magnetic media will be experienced. Over 150°F deterioration becomes more rapid. There is also a lower limit of temperature tolerance.

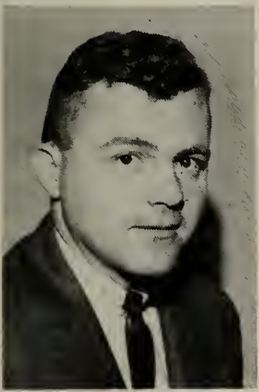
Another misconception is vulnerability to magnets. Magnetism is a very weak force which falls off very rapidly with distance. A magnet has to be very powerful and extremely close to the affected surface in order to cause a problem.

The organization's vital records program should lead to a "vital" classification for many programs, master files, transaction files, and related systems documentation. They merit top protection. A separate room is desirable for storage of this valuable property with very strict access control. If possible, a librarian should be constantly responsible for these media. Media should be released just before use and returned to secure storage immediately after use. Dual tapes should be run and the storage of one should be in an off-site location. The records management system must be periodically reviewed to make sure it is working properly (in one company, managers discovered that persons were getting into a locked media library during non-working hours through a false floor).

Smaller organizations should also consider vault or safe storage with sprinkler protection.

In conclusion, the problems in the design of computer rooms are many and varied, but good planning (and an adequate budget) can eliminate future computer down-time, physical loss and consequently loss of revenue to the company.

Report of Committee 7—Timber Structures



W. S. Stokely,
Chairman
J. A. Gustafson,
Vice Chairman
J. W. Chambers,
Secretary

J. Budzileni
J. M. Helm
J. H. Huzy
G. N. Sells
L. R. Kubacki
H. R. Stokes
B. J. King
D. L. Walker
M. J. Marlow
R. E. Anderson
D. O. Barth
B. Bohannan
T. E. Brassell
N. D. Bryant
G. K. Clem
F. H. Cramer (E)
A. R. Dahlberg
B. E. Daniels
K. L. DeBlois (E)
D. J. Engle
S. L. Goldberg
D. C. Gould
R. W. Gunther
J. A. Hawley
J. E. Holmberg*
J. E. Hutto
C. D. Jordan
W. C. Kirkland
D. I. Kjellman
H. G. Kriegel
R. E. Kuehner
C. V. Lund (E)
D. H. McKibben
C. H. Newlin
W. A. Oliver
N. I. Pinson
R. P. Rasho
J. J. Ridgeway
D. V. Sartore
F. E. Schnider (E)
J. W. Storer
R. W. Thompson
W. A. Thompson
N. E. Whitney
A. Youhanaie
S. J. Zajchowski
Committee

---

* Died July 26, 1973.

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
As previously reported, the subcommittee has completed the details of decimalization and reorganization of Chapter 7. However, in the interest of economics, this work will not be published until such time as the current work of subcommittees working on Assignments 2 and 3 report their work ready for publication.

2. Grading Rules and Classification of Lumber for Railway Use; Specifications for Structural Timber, Collaborating with Other Organizations Interested.
The work of development of the various allowable stresses is complete and in the hands of the subcommittee membership for review and approval.

3. Specification for Design of Wood Bridges and Trestles.
The basic work on the Design section of the re-organized material is now reported out of subcommittee. Full committee action on this work will have first priority during the coming year.

4. Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints.

   This subcommittee now has access to records and information concerning the application of a spray-on fire retardant to a timber trestle. These data are to be developed into an informational report during the coming year.

5. Design of Structural Glued Laminated Wood Bridges and Trestles.
   This subcommittee continues to work with various parties in the development of acceptable lay-ups and allowable stresses.

6. Evaluation of Cost of Various Sizes of Bridge Timbers.
   Final report, presented as information .... page 317

7. Repeated Loading of Timber Structures.
   This subcommittee continues its review of the results of AAR Technical Center Report LT 342. A final disposition of this matter is expected during the coming year.

8. Protection of Pile Cut-Offs; Protection of Piling Against Marine Organisms by Means Other Than Preservatives.
   No report.

9. Study of In-Place Preservative Treatment of Timber Trestles.
   The previously reported on in-place preservative treatments now approach their tenth anniversary and the subcommittee is making arrangements to again evaluate the levels of preservative remaining in the treated areas.

10. Non-Destructive Testing of Wood.
    The subcommittee, during the past year, has developed one additional source of possible interest to the membership. During the coming year, the three methods are to be followed to the extent that application and cost, with respect to in-place bridge timber testing, can be reported on.

THE COMMITTEE ON TIMBER STRUCTURES,
W. S. STOKELY, *Chairman.*

Report on Assignment 6

Evaluation of Cost of Various Sizes of Bridge Timbers

L. R. Kubacki *(chairman, subcommittee),* J. W. Chambers, T. E. Brassell, D. C. Gould, J. A. Hawley, J. E. Hutto, W. C. Kirkland, D. I. Kjellman, R. P. Rasho, D. V. Sartore, N. E. Whitney.

The purpose of this assignment was to develop the relative costs between solid-sawn timber trestle members in which cross-sectional dimensions were selected in strict accordance with calculated load-allowable stress relationships and trestle members in which cross-sectional dimensions were selected with respect to sizes usually produced as well as load-allowable stress calculations.

The method of data gathering involved the development of a bill of materials which included the desired variables, and the handling of this bill with the purchasing departments of railroad companies for price quotation inquiries. The inquiries were processed three times. The response to these inquiries was only partial and, for the purpose of the study, inadequate.

Further efforts to develop meaningful costs or cost indices under the scope of this assignment are currently expected to meet with similar results, and it is recommended that the assignment be closed.

Report of Committee 8—Concrete Structures and Foundations

T. L. Fuller, *Chairman*
J. W. DeValle,
Vice Chairman
R. J. Brueske
J. R. Moore
G. W. Cooke
J. M. Williams
J. R. Williams
W. F. Baker
E. R. Blewitt
W. E. Brakensiek
G. F. Dalquist
M. T. Davisson
J. T. Doherty
B. M. Dornblatt
R. A. Dorsch
D. H. Dowe (E)
M. E. Dust
F. C. Edmonds
J. A. Erskine
Bernard Fast
G. W. Gabert
W. L. Gamble
E. F. Grecco
R. J. Hallawell
W. A. Hamilton, Jr.
C. W. Harman
P. Haven, II
W. P. Hendrix
J. O. Holladay
H. W. Hopkins
A. K. Howe
W. R. Hyma
J. R. Iwinski
T. F. Jacobs
T. R. Kealey
F. A. Kempe
R. H. Kendall
F. W. Klaiber
Louis Lange, Jr.
R. H. Lee
G. F. Leyh
J. K. Lynch
E. F. Manley
E. C. Mardorf
J. F. Marsh
L. M. Morris (E)
E. S. Neely, Sr.
D. Novick
R. E. Pearson
J. A. Peterson
J. E. Peterson
M. Pikarsky
H. D. Reilly
E. D. Ripple
E. E. Runde
J. H. Sawyer, Jr.
M. P. Schindler
J. E. Scroggs
J. R. Shafer
L. F. Spaine
C. H. Splitstone (E)
W. B. Stanczyk
R. G. Stilling
A. Tedesko
W. C. Teng
M. F. Tigrak
W. J. Venuti
J. W. Weber
J. O. Whitlock
W. R. Wilson (E)
G. A. Wolf
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Manual recommendations submitted for adoption were published in Part 1 of Bulletin 650, November–December 1974.

1. Design of Masonry Structures, Collaborating as Necessary or Desirable with Committees 1, 5, 6, 7, 15 and 28.
Brief status statement, submitted as information .... page 320

2. Foundations and Earth Pressures, Collaborating as Necessary or Desirable with Committees 1, 6, 7, and 15.
Brief progress report, submitted as information .... page 320

3. Waterproofing for Railway Structures, Collaborating as Necessary or Desirable with Committees 6, 7 and 15.
   Brief progress report, submitted as information .... page 321

4. Concrete Components for Timber Trestles, Collaborating as Necessary or Desirable with Committee 7.
   Final report, submitted as information .... page 321

THE COMMITTEE ON CONCRETE STRUCTURES AND FOUNDATIONS,

T. L. FULLER, *Chairman.*

Report on Assignment 1

Design of Masonry Structures

J. R. MOORE *(chairman, subcommittee)*, W. F. BAKER, W. E. BRAKENSIEK, J. W. DEVALLE, J. T. DOHERTY, R. A. DORSCH, M. E. DUST, F. C. EDMONDS, J. A. ERSKINE, T. L. FULLER, G. W. GABERT, W. L. GAMBLE, E. F. GRECCO, W. A. HAMILTON, C. W. HARMAN, W. R. HYMA, F. A. KEMPE, F. W. KLAIBER, R. H. LEE, G. F. LEYH, J. K. LYNCH, J. F. MARSH, R. E. PEARSON, J. E. PETERSON, E. D. RIPPLE, J. H. SAWYER, J. E. SCROGGS, L. F. SPAINE, A. TEDESKO, M. F. TIGRAK, W. J. VENUTI, J. W. WEBER, J. O. WHITLOCK, J. R. WILLIAMS, W. R. WILSON, G. A. WOLF.

Revisions to Manual material submitted for adoption were published in Part 1 of Bulletin 650, November–December 1974. This included revisions to pier protection requirements for bridges crossing over railroad tracks.

The subcommittee is continuing work on changing design loading to E 80 from E 72 and other upgrading of the design portions of the manual.

Work has commenced on ultimate strength load factor design as a possible alternate to working stress design for concrete bridges. Standard concrete spans (designed by working stress method) are being analyzed by load factor design and ultimate strength methods to develop correlations between the methods.

Report on Assignment 2

Foundations and Earth Pressures

G. W. COOKE *(chairman, subcommittee)*, G. F. DALQUIST, M. T. DAVISSON, B. M. DORNBLATT, B. FAST, P. HAVEN II, R. J. HALLAWELL, J. O. HOLLADAY, T. R. KEALEY, R. H. KENDALL, E. F. MANLEY, E. C. MARDORF, D. NOVICK, M. P. SCHINDLER, J. R. SHAFER, W. B. STANCZYK, W. C. TENG.

Revisions to Manual material submitted for adoption were published in Part 1 of Bulletin 650, November–December 1974. This included entire new Part 3—Specifications for Design of Spread Footings.

Work is in progress for revisions to Part 4—Pile Foundations, and to Drilled Shafts and Caissons, originally published as information in Bulletin 641, January–February 1973.

Work is in progress to discover reasons for inconsistencies in the results obtained using the Coulomb and Boussinesq formulas in Part 20 for point, line and strip surcharge loadings.

Report on Assignment 3

Waterproofing for Railway Structures

J. M. Williams *(chairman, subcommittee)*, E. R. Blewitt, W. P. Hendrix, H. W. Hopkins, A. K. Howe, J. R. Iwinski, L. Lange, M. Pikarsky, H. D. Reilly, E. E. Runde, R. G. Stilling.

Revisions to Manual material submitted for adoption were published in Part 1 of Bulletin 650, November–December 1974. This covered asphaltic panel protective course over membrane waterproofing.

Work is in progress for possible inclusion of ethylene-propylene-diene-monomer (EPDM) as an alternate to butyl membrane or rubberized asphalt and plastic film membrane.

Report on Assignment 4

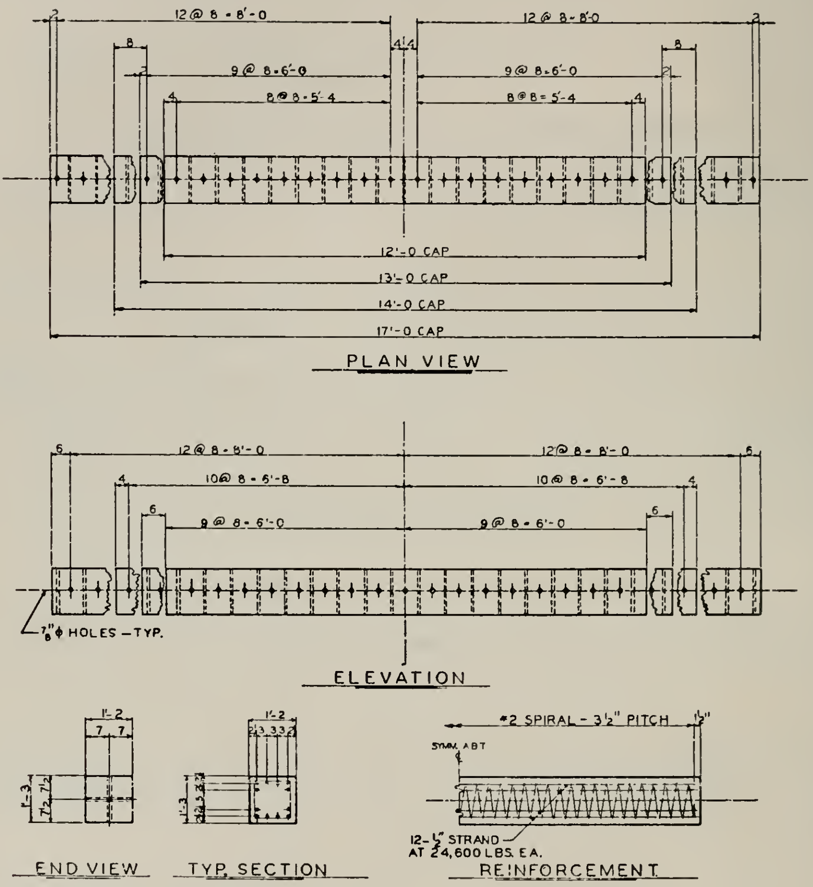
Concrete Components for Timber Trestles

J. R. Williams *(chairman, subcommittee)*, W. F. Baker, J. W. DeValle, G. W. Harman, J. R. Iwinski, E. E. Runde, J. E. Scroggs.

The subcommittee has completed plans for a precast, prestressed concrete cap for usage in timber trestles. This cap was developed to meet the various requirements of railroads presently using concrete caps in conjunction with suppliers of those caps. Standardization on the recommended cap should benefit both users and suppliers. Typical connection details were also developed.

Details of cap and connections are shown as information (see pages 322 and 323) with recommendation that they eventually be adopted and published in the Manual.

This is the final report of Subcommittee 4, and subcommittee is abolished.

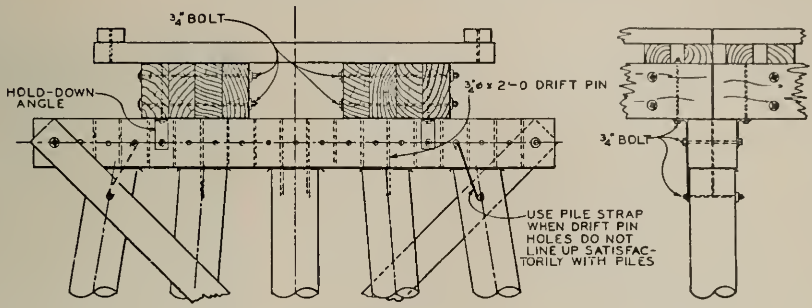


GENERAL NOTES

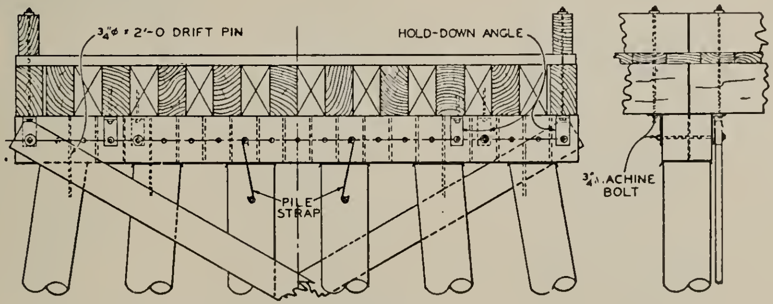
1. CAP TO BE MANUFACTURED IN ACCORDANCE WITH A.R.E.A. SPECIFICATION 17.
2. CONCRETE = 6,000 PSI AT 28 DAYS
3. CEMENT = A.S.T.M. C-150 UNLESS NOTED.
4. AGGREGATES = ¾" MAX.
5. STRAND = A.S.T.M. A-416
6. REINFORCING = A.S.T.M. A-82
7. FINISH = AS FORMED FREE FROM HONEYCOMB OR VOIDS.

CAP WEIGHTS	
LENGTH	WT. LBS.
12'-0	2600
13'-0	2850
14'-0	3050
17'-0	3700

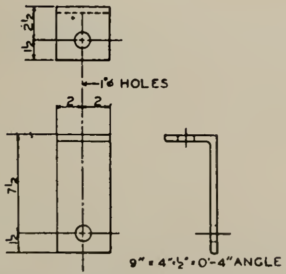
Prestressed concrete cap for timber pile trestles.


3/4" BOLT
HOLD-DOWN ANGLE
3/4"⌀ x 2'-0 DRIFT PIN
3/4" BOLT
USE PILE STRAP WHEN DRIFT PIN HOLES DO NOT LINE UP SATISFACTORILY WITH PILES

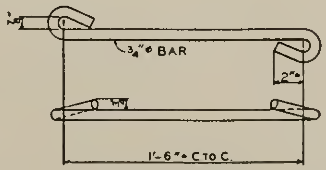
5 PILE-OPEN DECK



6 PILE-BALLAST DECK



HOLD-DOWN ANGLE



PILE STRAP

Typical methods of fastening concrete caps.

Report of Committee 16—Economics of Plant, Equipment and Operations

W. G. Byers, *Chairman*

M. B. Miller,
Vice Chairman

R. W. McKnight,
Secretary

G. Rugge
J. R. Wilmot
T. C. Nordquist
R. P. Hoffman
D. H. Noble
T. D. Kern
R. D. Penhallegon
J. C. Martin

R. E. Ahlf
C. Bach
J. W. Barriger (E)
J. W. Barriger
K. W. Bradley
R. L. Carstens
J. B. Clark
R. P. Cornwall
L. P. Diamond
W. J. Dixon
R. H. Dunn
L. A. Durham, Jr.
G. B. Dutton, Jr.
J. J. Eash
S. Fogarty, Jr.
J. A. Forbes
B. G. Gallagher
G. R. Gaspard
A. J. Gellman
A. M. Handwerker
G. E. Hartsoe
W. W. Hay
L. W. Haydon
E. C. Honath
G. R. Janosko
H. J. Kay
H. C. Kendall
T. J. Lamphier
R. J. Lane
A. S. Lang
K. L. Lawson
J. H. Marino
R. G. Maughan

R. McCann
R. L. Milner (E)
R. L. McMurtrie
C. J. Meyer
J. Neben
J. F. Partridge
W. L. Paul
J. S. Reed
F. J. Richter
V. J. Roggeveen
A. L. Sams
R. J. Schiefelbein
J. H. Seamon
M. J. Shearer, Jr.
T. C. Shedd
L. K. Sillcox (E)
M. L. Silver
T. H. Sjostrand
J. J. Stark, Jr.
J. M. Sussman
G. M. Tabor
J. E. Teal (E)
C. L. Towle (E)
R. Turner
D. E. Turney, Jr.
K. B. Ullman
H. Wanaselja
L. E. Ward
F. Wascoe
D. M. Weinroth
D. B. Weinstein
P. B. Wilson
T. D. Wofford, Jr.
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
The first section of Part 6, Industrial Engineering, has been completed and will be published following letter-ballot approved by the committee. The outline for the portion of Chapter 16 concerned with electrification is being revised because a portion of this material is now under the jurisdiction of the Committee on Electrical Energy Utilization.

2. Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service.
A literature search resulting in summaries of 264 published articles and papers dealing with the quality of railroad freight service was per-

formed for the committee by Railroad Research Information Service. A report on the quality of service in which problems are defined, solutions described and current work abstracted is being prepared.

3. Determination of Factors, Including Various Traffic Volumes, Affecting Maintenance of Way Expense and Effect of Using Such Factors, in Terms of Equated Mileage or Other Derived Factors, for Allocation of Available Funds to Maintenance of Way, Collaborating as Necessary or Desirable with Committees 11 and 22.
   (a) Additional Maintenance Cost Due to Operating 100-Ton Unit Trains.

   Most of the effort related to this assignment is being directed toward the unit-train problem (Subassignment a) which is a new assignment this year. A special feature related to this problem is being planned for the 1975 Technical Conference, and a report supplementing the special feature will be prepared following the Technical Conference.

4. Economic Evaluation of Methods for Reducing the Probability of Derailments.

   Following publication of material on derailment investigation procedures and derailment data reporting by the Association of American Railroads and Department of Transportation, a report on systems for collecting and analyzing derailment data will be prepared.

5. Economics of Freight Cars with Characteristics Approaching the Limits of Accepted Designs.
   A report on this subject was published in Bulletin 649, September–October 1974.

6. Factors Involved in Rationalization of Railway Systems.
   Specific topics expanding and illuminating the List of Factors reported previously (Progress Report in January–February 1974 Bulletin) are being researched and will be reported in future Bulletins.

7. Applications of Industrial Engineering Functions to the Railroad Industry.

   Subcommittee 7 has been collaborating with Subcommittee B on preparation of material on industrial engineering for the Manual.

8. Economics of Systems for Control of Train Operation.
   A report describing the various available systems and discussing their economics is being prepared and should be ready for publication in 1975.

THE COMMITTEE ON ECONOMICS OF PLANT, EQUIPMENT AND OPERATIONS,

WM. G. BYERS, *Chairman.*

Report of Committee 22—Economics of Railway Construction and Maintenance

H. C. Minteer,
Chairman

John Fox,
Vice Chairman

P. A. Cosgrove,
Secretary

J. A. Caywood
J. T. Sullivan
J. R. Naylor
J. D. Vaughan, Jr.
T. P. Woll
W. J. Jones
R. J. Aschmeyer
F. S. Barker
A. S. Barr
C. D. Barton
H. B. Berkshire
A. Bornhoft
J. W. Brent
J. S. Busby
L. B. Cann, Jr.
A. W. Carlson
J. R. Clark
W. H. Clark
S. A. Cooper
M. H. Dick
H. B. Durrant
L. C. Gilbert
W. Glavin
C. R. Harrell
W. H. Hoar
B. G. Hudson
J. C. Hunsberger
J. T. Hunter
R. D. Johnson
C. Johnston
T. L. Kanan
H. W. Kellogg (E)
H. W. Kimble
W. E. Laird
B. Liljeblad
L. A. Loggins (E)
J. M. Lowry
A. L. Maynard
J. R. Miller
E. T. Myers
G. M. O'Rourke (E)
M. E. Paisley
R. W. Pember
G. G. Phillips
C. T. Popma
R. W. Preisendefer
F. L. Rees
M. S. Reid
C. L. Robinson
M. Rougas
G. E. Scholze
H. W. Seeley
A. E. Shaw, Jr.
R. G. Simmons
N. E. Smith
W. B. Stackhouse
J. Stang
J. E. Sunderland
W. A. Swartz
S. W. Sweet
D. D. Thomas
H. J. Umberger
J. T. Ward
G. E. Warfel
H. E. Wilson
G. H. Winter
F. R. Woolford (E)
B. J. Worley
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
A complete revision of Chapter 22 of the Manual was published in Part 1 of Bulletin 645, November–December 1973. Portions of this Manual material are now being reviewed.

1. Analysis of Operations of Railways That Have Substantially Reduced the Cost of Construction and Maintenance Work.
Progress report, presented as information .... page 328

2. Study to Establish New Equated Mileage Parameters.
No report.

3. Economics of Producing Continuous Welded Rail by In-Track Welding. When this subject was assigned, it was thought that a means of welding rail in track was available and would be put to use by several railroads. However, it appears that the process and expense could not be justified.

4. Use of Track Analyser Car in Inspection of Track and Maintenance Planning, Collaborating as Necessary or Desirable with Committee 5. The current report of Subcommittee 1 deals partly with this subject, and the study will be continued as information is developed.

5. Comparative Costs of Cleaning Ballast vs. Ballast Replacement in Track Rehabilitation.
   No report.

THE COMMITTEE ON ECONOMICS OF RAILWAY CONSTRUCTION AND MAINTENANCE,

H. C. MINTEER, *Chairman.*

Report on Assignment 1

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Construction and Maintenance of Way Work

J. T. SULLIVAN *(chairman, subcommittee)*, H. B. BERKSHIRE, ARLIE BORNHOFT, L. B. CANN, JR., A. W. CARLSON, W. H. HOAR, C. T. POPMA, R. W. PREISENDEFER, G. E. SCHOLZE, A. E. SHAW, JR., D. D. THOMAS, H. J. UMBERGER, H. E. WILSON, F. R. WOOLFORD.

This report is submitted as information. It deals with the United States Department of Transportation High Speed Ground Test Center at Pueblo, Colorado.

A 5½- by 9-mile site, located approximately 20 miles from Pueblo, was selected in December 1969 and inaugurated in August 1970 as the U. S. Department of Transportation's research facility and test center for ground transportation systems. When completed, the center will be the biggest and most sophisticated test bed of its kind in the world.

Managed by the Federal Railroad Administration, the center will enable the Department of Transportation to test all types of equipment and vehicles under extreme weather and different terrain conditions—an important consideration in the final selection of the Pueblo site.

Average daily temperatures range from 15° F in the winter to 90° F in the summer, with great daily temperature variations. Average annual rainfall is 11.84 inches and snowfall 31.7 inches.

The relatively flat 52.6-square-mile area, leased from the State of Colorado for 50 years, is a mile high.

The center was created to meet three broad objectives:

1. To assist in advancing the technology of ground transportation, including present rail, future high-speed rail and advanced systems.

2. To test the design of equipment components and entire systems, and demonstrate their reliability and serviceability.
3. To develop performance data on potential systems for intracity and intercity ground transportation.

To meet these objectives, the Department of Transportation has completed or is in the process of planning and constructing a complex of almost 30 miles of conventional track and more than 54 miles of specialized guideways. They include:

A 13.5-mile high-speed closed loop track for testing conventional freight and passenger trains at speeds up to 160 mph;

Within this oval, a 5.7-mile subordinate track for investigating passenger and freight train dynamics at speeds up to 50 mph.

A branch from the train dynamics track, consisting of an 0.8-mile impact track for scientific destructive testing.

A 9.1-mile rail transit test track, incorporating an electrified third rail, used by the Urban Mass Transportation Administration to test rapid transit cars at speeds up to 80 mph.

A 6.2-mile oval track, with a vertical reaction rail erected in the center line, for testing the Linear Induction Motor Research Vehicle (LIMRV) designed for speeds up to 250 mph;

A 21.8-mile oval cement slab guideway, with a vertical reaction rail in the center line, which is used to explore the technology of tracked levitated vehicles (TLV), to be powered by linear induction motors (LIMs) at speeds up to 300 mph.

A 5-mile cement slab guideway, with a vertical reaction and support rail in the center line, for testing a passenger-carrying prototype of a tracked air cushion vehicle (TACV), powered by a linear induction motor (LIM), at speeds up to 150 mph.

Existing and new equipment, including locomotives, passenger and freight cars, and advanced tracked systems, will be tested under controlled conditions in a 60,000-sq ft Rail Dynamics Laboratory. The laboratory will house the world's most advanced, computer-controlled simulator which will permit simulation of speeds up to 288 mph. Programs to be conducted include evaluation of passive and active suspensions for better ride quality at high speeds, determination of derailment causes, and solving the problem of freight car instability.

Through these facilities, the Department is providing for the first time in this country, a major installation to apply the best of modern technological capability to surface transportation systems. This need becomes even more important as the Nation strives to achieve its energy and environmental goals. Public ground transportation uses energy efficiently and is attractive environmentally. A number of testing programs sponsored by the Department's Federal Railroad Administration and Urban Mass Transportation Administration are underway or in the planning stage. The facilities at Pueblo are also available to U. S. industry and foreign countries under suitable arrangements.

The testing program includes work to determine the limits of performance of today's freight trains and components and developing improvements in them in terms of safety, performance and efficiency. Freight car suspension systems as they affect the stability of freight cars and the possible damage to contents will be tested over various track conditions in the Rail Dynamics Laboratory. Entire train systems will be tested on the dynamics track to find out how best to design and operate trains that pass over severe curves and grades.

Similarly, passenger cars—those for urban transit and ones intended for intercity use—can be tested in the Rail Dynamics Laboratory and put through extensive checking on the Transit Test Track and the conventional intercity track loop. These tests are aimed at improving ride comfort, safety, reliability, and speed.

A locomotive geared for high-speed service has been tested on the dynamics track to obtain technical data on its suspension system for reliability purposes and determine its effect on the track. Grade crossing accidents and train impact tests are conducted on the specially constructed impact track.

Track construction and maintenance is a costly and vital element in the safety and performance of all rail operations. Through tests in these facilities, a better understanding of the effects of various types of track defects and track conditions on such matters as derailments and ride quality can be determined. This information can then provide a scientific basis for optimizing track requirements and testing the effects of new types of track construction.

Long-range transportation needs may well be met with ground transportation systems more advanced than can be achieved through simple improvements of today's systems. Since the speed of conventional wheeled vehicles is limited by wheel/rail adhesion, higher speeds could be achieved by eliminating wheels and rails. This has led to the exploratory development of the tracked levitated vehicle (TLV). Such a vehicle could be suspended a fraction of an inch to a few inches above a specially constructed guideway by a cushion of air or magnetic forces. Without wheels, such a vehicle cannot be powered by conventional traction motors. This has led to the development of linear motors, which propel by electromagnetic forces, and, since they have no moving parts, are noiseless and vibrationless and can be operated with low pollution.

Exploratory testing of such systems also is underway by FRA at the Test Center. A linear induction motor (LIM)—essentially a rotary motor unrolled and laid out flat—is being tested in a vehicle designed for this purpose. This Linear Induction Motor Research Vehicle (LIMVR), still riding on wheels on tracks, is designed for speeds to 250 mph.

The technology of TLVs is being developed through the use of a Tracked Levitated Research Vehicle (TLRV) operating on its specially constructed guideway. The vehicle, levitated by cushions of air, is designed so various changes in configuration can be made as more is learned about TLVs. The TLRV has jet engines for air supply and some propulsive capacity. Full propulsion uses linear motors. The same guideway facility is intended to be used for exploring magnetic levitation for TLVs.

A prototype of a passenger-carrying tracked air cushion vehicle is also scheduled for testing. Designed for 150 mph, it is intended to demonstrate for regional transportation planners the potential for such systems.

Through these advanced activities, the FRA is developing the technology of systems in the 150-300 mph range which can provide the basis for the transportation system decisions of the late 1970's and 1980's.

Track Inspection Cars

In addition, the Federal Railroad Administration is involved in a major program for developing a system for the inspection, measurement and evaluation of today's railroad track.

Track inspection has always been an essential part of good railway maintenance. By inspecting track, one can find out what is wrong and gain necessary knowledge to program maintenance work.

Inspection covers all measurement appraisal and evaluation of track. Inspections are made to determine the best course of action and to help make valid maintenance decisions. Inspection information can be used to determine the best manner in which to spend allocated funds for material, labor and tools.

However, the kinds of information required by a track foreman differ widely from that required by management. For example, to detect which of several rail sections needs immediate attention demands one kind of information. To systematically divide a maintenance budget among territories requires another. To decide if the track meets specified safety standards is still another. Management needs the data for planning and funding maintenance programs; maintenance personnel need the information to evaluate track quality and expedite repairs. The same data is used in each case, only the manner of presentation is different.

Recent railroad mergers and consolidations have tended to increase the territory of track supervisors to the point where frequent surveillance is an immense task. In some locations, there is a shortage of highly trained and experienced personnel capable of making the difficult decisions required in track evaluation. Pressures to reduce expenditures are delaying required programs. These factors are reducing track inspection capability, while at the same time, increased train speed, greater wheel loads and new car designs place increased demands for higher quality track.

The answer is simple: high-speed automated track inspection. Automated track inspection has the advantage that dangerous or unsafe track/roadbed conditions can be detected and corrected immediately. Maintenance activities can be planned and scheduled. Track conditions and degradation rate can be correlated with traffic load and speed.

Today, automated measurement of track geometry is both technically feasible and economically attractive. Track inspection cars can measure all of the elements of track geometry and, through the use of computers, it is possible to assimilate the information and process the data in about any way desired. However, the track inspection cars cannot give opinions. They merely report information in very factual, objective terms. The maintenance officer responsible must form the opinions to make the necessary judgments and decisions.

The Department of Transportation is performing research in this area with four government-owned test cars specially developed for the program.

The test cars are normally used in pairs and are scheduled on a year-round basis for various tests which support specific research program objectives. Test cars T2 and T4 are presently multipurpose vehicles which have been used for a variety of applications including studies of vehicle dynamics, ride quality, and pantograph/catenary and wheel/rail interactions.

Test cars T1 and T3 are normally used for tests requiring the acquisition of track geometry data. Test car T1 is a support vehicle necessary for extended tests. Test car T3 contains an advanced track geometry measuring system which includes a computer-based, general purpose data acquisition system, and a complete instrumentation package for high-speed high-resolution measurements of track geometry.

The track geometry system in test car T3 utilizes noncontacting sensors to measure sensor-to-rail distances from which rail profile and alignment in terms of mid-chord offsets, and track gage are derived; these are shown in Fig. 1. In addition, instrumentation for measuring rail profile using inertial reference lines is also installed. Similar instrumentation for measuring rail alignment is under development.

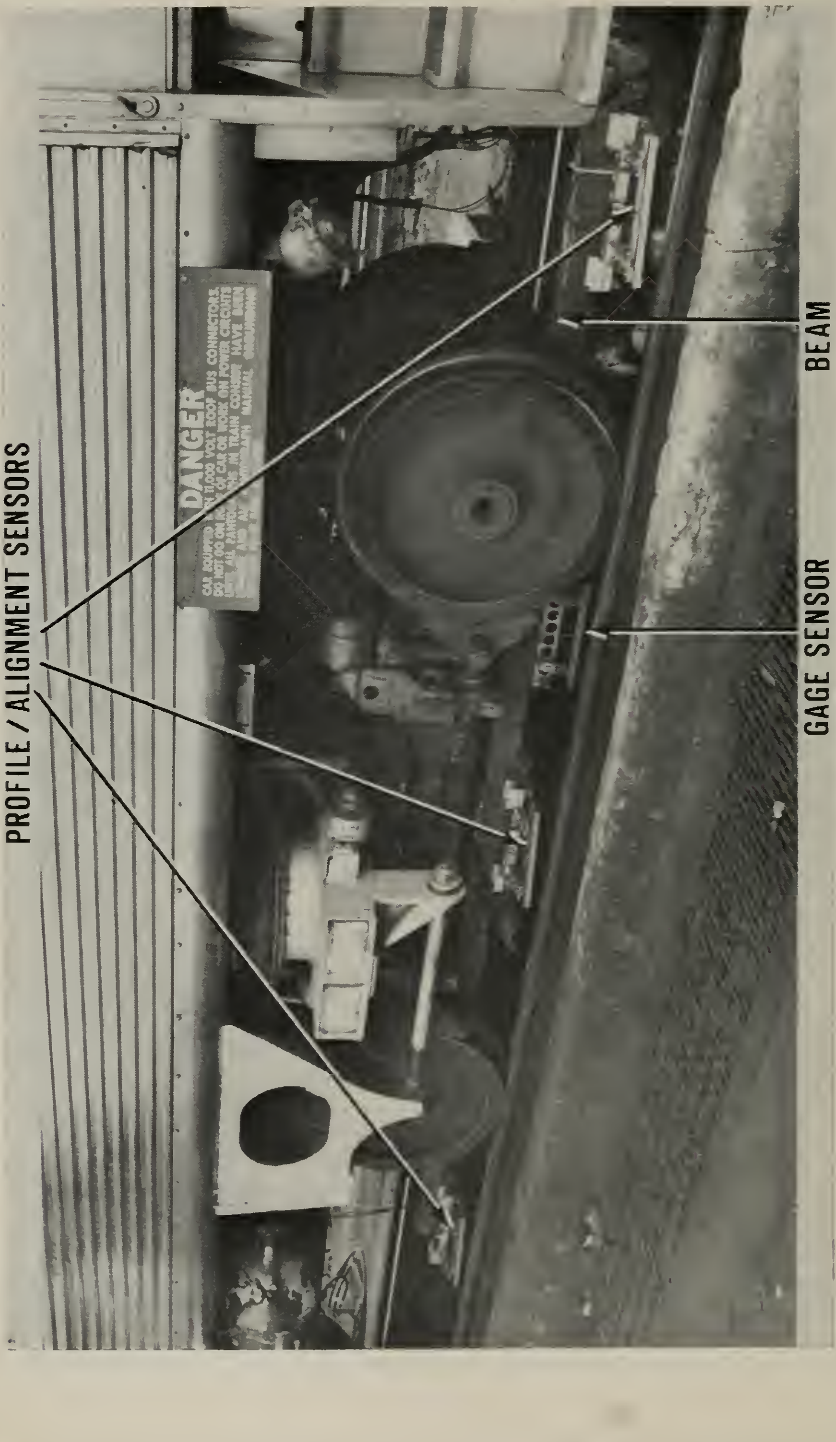


Fig. 1—Track geometry system sensor beam.

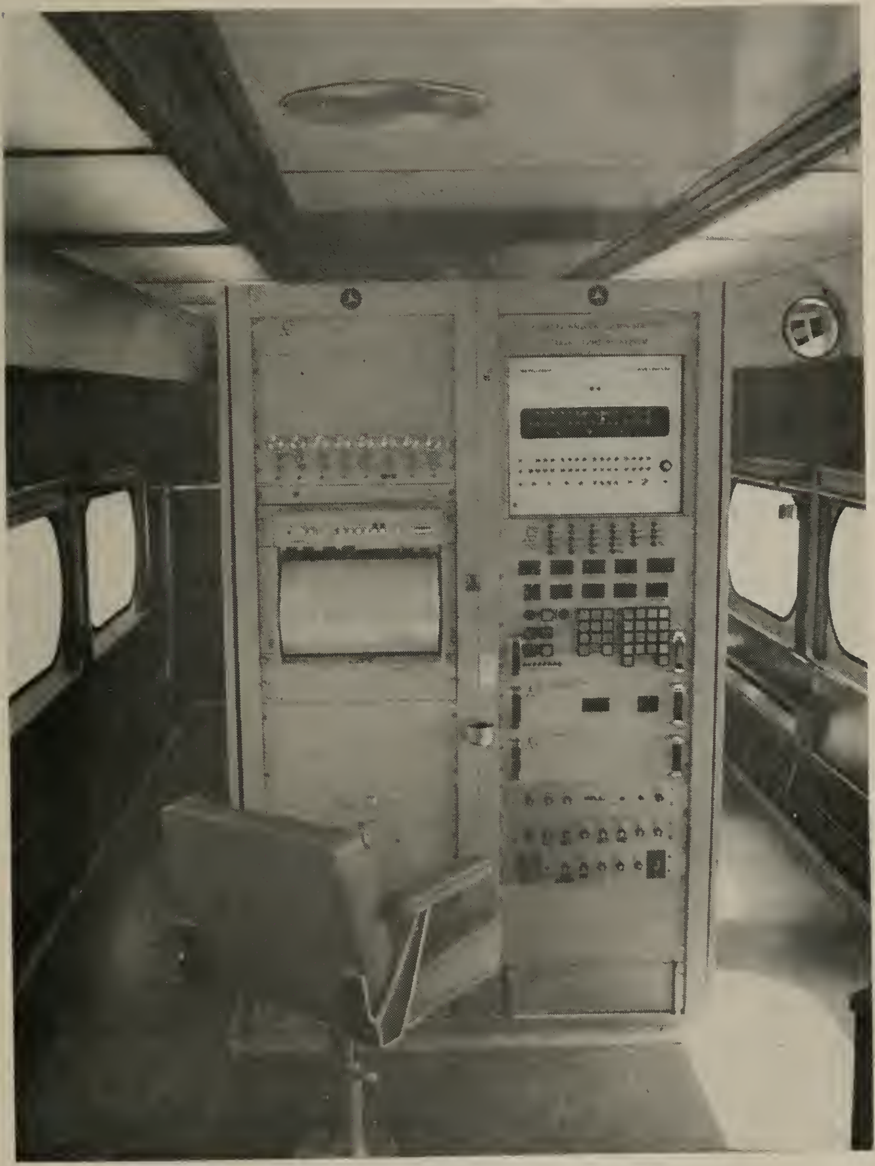


Fig. 2—Track geometry computer system.

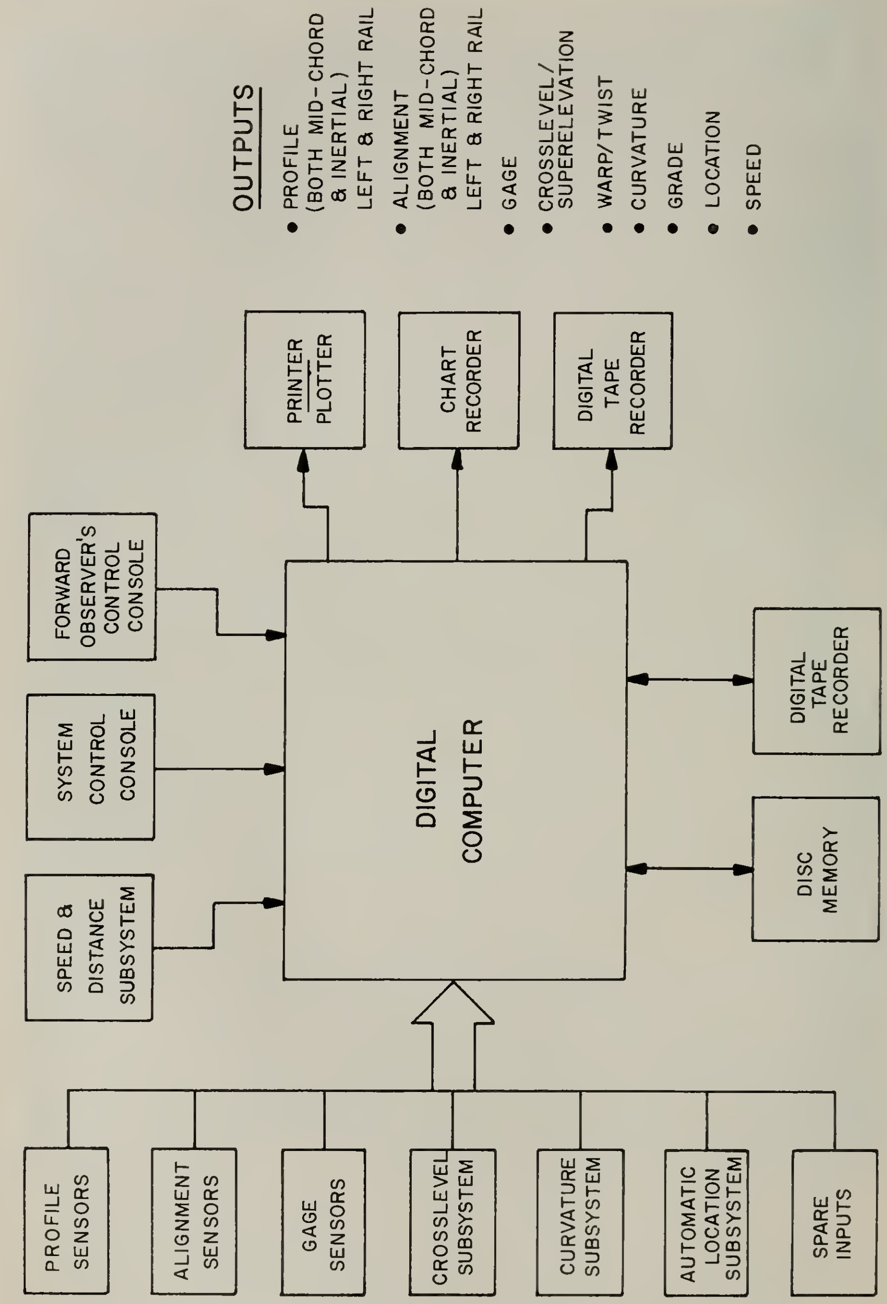


Fig. 3—Track geometry system functional diagram.

The analog signals from each of the sensors are sampled every 2.4 ft and then digitized and input to a digital computer. Milepost information, track locations, environmental conditions and other factors are input manually by a forward observer. With this information, accurate track defect/geography correlation is possible. Individual sensor values are recorded on digital magnetic tapes and computed track geometry parameter values are displayed on an analog chart recorder. Severe track defects are printed on an electrostatic printer/plotter. The track geometry computer system is shown in Fig. 2 and the overall measurement system is shown in block diagram form in Fig. 3.

While all of the acquired data is being recorded on both digital magnetic tapes and chart recordings, the computer is also continuously comparing the data to preselected limits for indications of critical track defects. Upon detection of such defects, appropriate information is immediately printed and made available to onboard track maintenance personnel. After the survey, digital magnetic tape recordings are processed to analyze and evaluate track conditions using more comprehensive approaches. Through this real-time and post-survey processing, both maintenance and managerial information is provided for corrective maintenance actions and for maintenance planning and control. Descriptions of this track maintenance information processing and examples of information reports are provided in the following paragraphs.

Processing conducted on the test cars during a track survey is called real-time processing and includes chart recordings and critical exception listings. Chart recorder displays are selectable and may include gage, cross level, warp, curvature, grade, profile, alignment, location, speed or vehicle acceleration. Fig. 4 is an example of a typical chart recording of track geometry data.

While chart recordings provide complete survey data, they are very cumbersome and difficult to use, especially in the field. In addition, most of the data represents trackage which does not require maintenance. To reduce data bulk, the concept of exception reporting has been applied extensively for near-term track maintenance purposes. Fig. 5 illustrates the exception reporting concept. Thresholds are established (57.0 inches for gage in the illustration), and each measurement is compared to a threshold value. When a threshold is exceeded, an exception exists. Exceptions are grouped and processed to specify their geographic location, magnitude and correlation with other track defects or major track characteristics, such as curves and turnouts.

Exception processing for critical defects is conducted in real-time. The onboard computer continuously examines the data for track geometry parameter values which exceed preselected thresholds. Upon detection of values greater than these thresholds, the geographic location and magnitude of the exceptions are printed in their appropriate columns (profile, alignment, gage, etc.). Locations are specified as mileposts plus distance in feet.

Processing conducted after the track survey is oriented towards long-term maintenance planning, e.g., months or years. To permit in-depth studies of track conditions, detailed information is provided for each track geometry parameter including gage, profile, cross level and curvature. The curvature evaluation report, Fig. 6, is typical of the detailed track geometry parameter reports. Data is processed in geographic sequence and the location and measurable information are printed for transition points, degree of curvature, superelevation, indicated operating speeds

(Text continued on page 340)

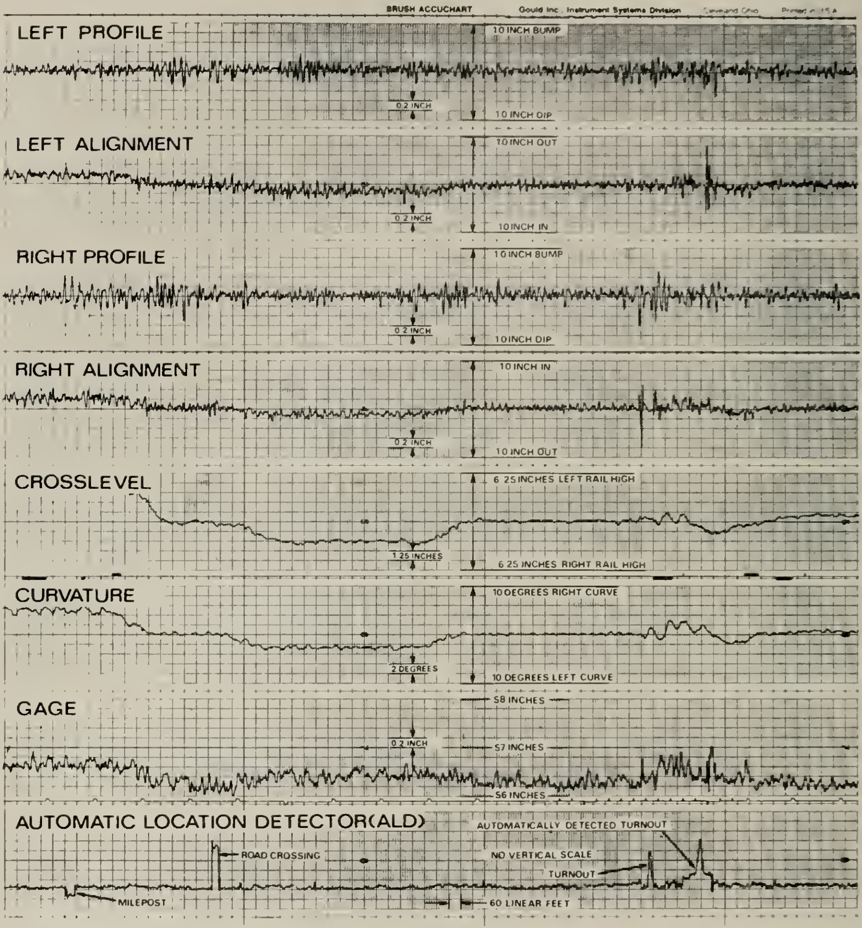
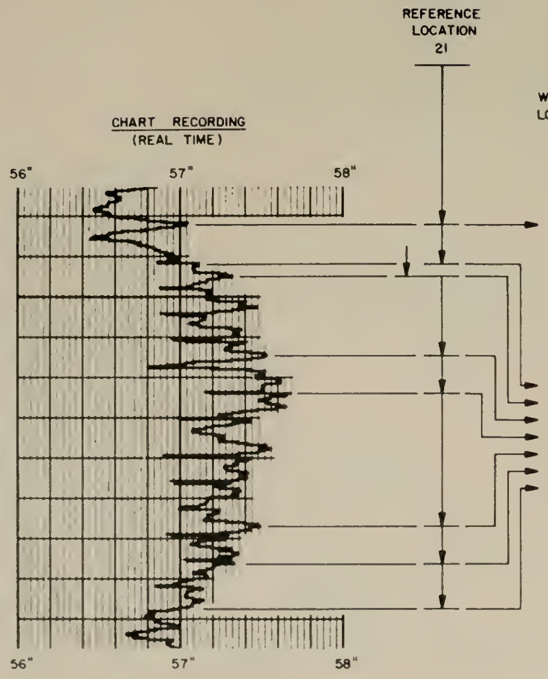
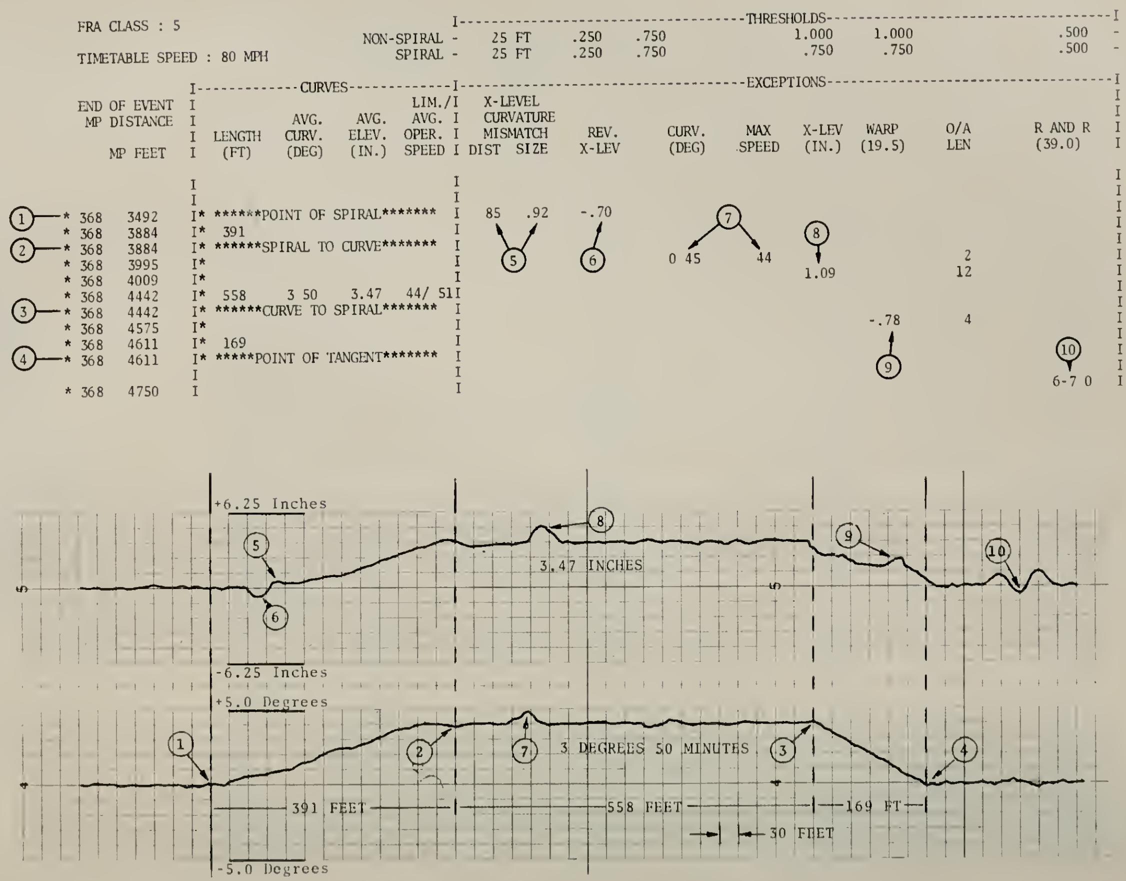


Fig. 4—Track geometry chart recording.



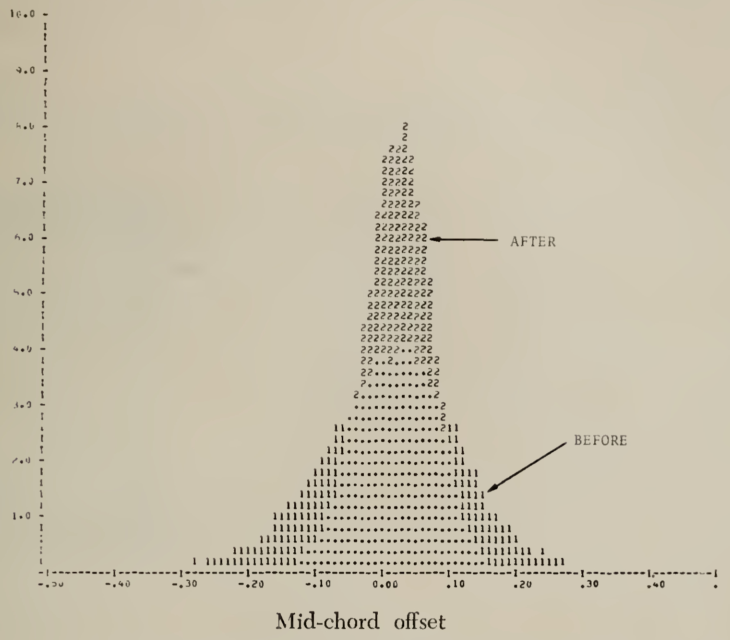
```
                         COMPUTER GENERATED EXCEPTION LISTING

WIDE GAGE EXCEPTIONS       ACQUISITION 10415-2N1        PROCESSED 04/17/71         PAGE 18
LOC X21   CENTRAL ROAD CROSSING MP 119.3   STANDARDS 57.00 57.25* 57.50** 57.75*** 58.00****


TRK/LOC   MILE   FEET   GAGE      O/A DIST   COMMENTS   EXC. INDEX   AVG. GAGE
 1 21      0      82    57.04        2                       3          57.04



 1 21      0     126    57.12                START
 1 21      0     150    57 28*
 1 21      0     270    57 52**
 1 21      0     330    57.68**                MAX
 1 21      0     527    57.50**
 1 21      0     575    57.34*
 1 21      0     637    57.08       511        END          833          57.32
```

Fig. 5—Exception reporting concept.

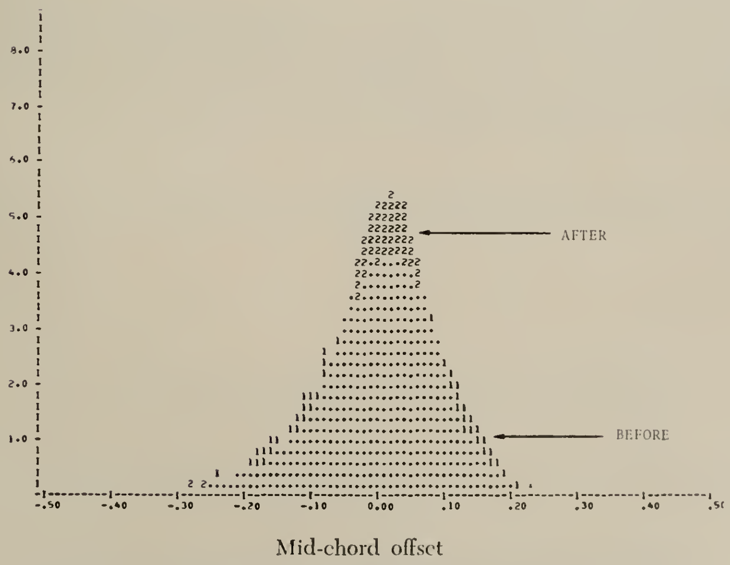


```
FRA CLASS : 5                                   I-----------------------------------THRESHOLDS-----------------------------------I
                                     NON-SPIRAL -   25 FT    .250   .750             1.000     1.000                  .500  -
TIMETABLE SPEED : 80 MPH                 SPIRAL -   25 FT    .250   .750              .750      .750                  .500  -

                I------------CURVES------------I-----------------------------------EXCEPTIONS---------------------------------I
END OF EVENT    I                       LIM./I X-LEVEL                                                                        I
 MP DISTANCE    I          AVG.   AVG.   AVG.  I CURVATURE                                                                    I
                I LENGTH   CURV.  ELEV.  OPER. I MISMATCH    REV.     CURV.   MAX    X-LEV   WARP    O/A      R AND R         I
   MP FEET      I  (FT)    (DEG)  (IN.)  SPEED I DIST SIZE   X-LEV    (DEG)   SPEED  (IN.)   (19.5)  LEN      (39.0)          I

                I                              I                                                                              I
                I                              I                                                                              I
①─* 368  3492   I* *****POINT OF SPIRAL******* I 85   .92    -.70             ⑦                                             I
  * 368  3884   I* 391                         I                                    ⑧                                         I
②─* 368  3884   I* *****SPIRAL TO CURVE******* I      ⑤       ⑥                                                               I
  * 368  3995   I*                             I                      0 45      44                    2                       I
  * 368  4009   I*                             I                                     1.09            12                       I
  * 368  4442   I* 558      3 50   3.47   44/ 51I                                                                             I
③─* 368  4442   I* *****CURVE TO SPIRAL******* I                                            -.78      4                       I
  * 368  4575   I*                             I                                                                              I
  * 368  4611   I* 169                         I                                                               ⑩              I
④─* 368  4611   I* *****POINT OF TANGENT*******I                                             ⑨                                I
                I                              I                                                                6-7 0         I
  * 368  4750   I                              I                                                                              I
```

Fig. 6—Detailed curve evaluation report.



a) Track surface improvement due to rail replacement.
(115-lb bolted rail replaced with 136-lb CWR)



b) Track surface improvement resulting from routine maintenance.
(Skin lift, 115-lb rail)

Fig. 7—Overlay profile data histograms.

and exceptions. The output format was developed in cooperation with several interested railroads.

To permit the relative comparisons of large sections of track or the qualitative assessment of the entire track property, information is provided in the form of histograms, graphs and tables of statistics. Histograms are used to indicate graphically the comparative quality of track sections. Showing the distribution, or range and concentration of data values, histograms permit an assessment of the general condition of several miles of track at a glance. Fig. 7 is an example of overlay histograms—histograms from one year superimposed over histograms from another year. This technique is being used to show track deterioration or improvement. In the examples shown, the histograms consisting of 1's and dots (dots are used where points are common to histograms for both years) represent sections where track data was obtained in 1971 before certain track maintenance was performed. The histograms consisting of 2's and dots represent the same sections where track data were obtained in 1972 after track maintenance was performed. Histograms statistics are also provided with overlay histograms to permit a quantitative assessment of changes in track conditions.

Organizational efficiency and effectiveness are dependent upon realistic planning and control. Some information is already available to facilitate managerial functions in the area of track maintenance. However, better information can always be developed. Efforts are underway to include Federal Railroad Administration Track Safety Standards as criteria for track maintenance evaluations. This will require substantial study of the trade-offs between track conditions and traffic requirements. From an economics standpoint, global track condition assessments and the general allocation of maintenance resources should be studied. This will lead further to the establishment of less empirical bases for the maintenance-of-way planning and budgeting process.

Current efforts in track maintenance information processing have been significantly influenced by the information requirements of users. Continuing communication between research organizations, the Federal Railroad Administration and the rail industry will ensure that new and better information is provided in consonance with needs of the user.

Report of Committee 13—Environmental Engineering

C. E. DeGeer, *Chairman*
W. H. Melgren,
Vice Chairman
A. J. Dolby, *Secretary*

R. C. Brownlee
R. R. Holmes
J. W. Zwick
R. S. Bryan, Jr.
J. L. Engler
D. S. Krieter
Barbara J. Rust
W. F. Arksey
H. W. Azer
R. A. Bardwell
R. G. Bielenberg
L. R. Burdge
J. C. Dietz
J. J. Dwyer (E)
J. H. Flett
J. W. Gwyn
W. M. Harrison
T. L. Hendrix
K. K. Hersey
J. D. Hoff, II
D. J. Inman
E. S. Johnson
F. L. Manganaro

W. D. Mason
H. L. McMullin (E)
R. G. Michael
P. M. Miller
E. T. Myers
J. C. Neal
G. H. Nick
M. F. Obrecht
W. D. Peters
R. Singer
R. J. Spence
T. A. Tennyson
R. J. Thompson
L. R. Tierney
J. W. Webb
D. R. York

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Under way are the updating of "Glossary of Terms and Directories of Pollution Control Agencies" and the reviewing of entire Section 6 for obsolescence.

1. Water Pollution Control.
No report.

2. Air Pollution Control.
The present task of this subcommittee is to revise and complete Section 2.1 Recommended Guide Standards, of Chapter 13 of the Manual.

3. Land Pollution Control.
Progress report, presented as information .... page 342

4. Industrial Hygiene.
Progress report, presented as information .... page 344

5. Plant Utilities—Design, Construction and Operation.
No report.

6. Corrosion Control.
   Section 6.5 Corrosion Control in Engine Cooling Systems, was published in Part 1 of Bulletin 650, November–December 1974, with the recommendation that it be adopted and published in the Manual.

7. Noise Pollution Control.
   No report.

THE COMMITTEE ON ENVIRONMENTAL ENGINEERING,

C. E. DEGEER, *Chairman.*

Report on Assignment 3

Land Pollution Control

A. J. DOLBY *(chairman, subcommittee)*, J. C. DIETZ, P. P. DUNAVANT, JR., T. L. HENDRIX, F. L. MANGANARO, R. SINGER, J. W. ZWICK.

Your committee submits as information the following report pertaining to the disposal of solid wastes, with the intention eventually to submit it for adoption and publication in Chapter 13 of the Manual.

3.5 DISPOSAL OF SOLID WASTES—PRACTICES AND RESEARCH NEEDS

3.5.1 State of the Art

(a) Twenty-one million ties are removed per year by the railroad industry, and it has been estimated that over 20,000,000 used ties are currently strewn along railroad right-of-ways. Most of these ties are cut into pieces during removal. The most notable exception to this procedure is the removal of ties from yard tracks.

(b) The most widely used method of tie disposal is to leave them on the right-of-way either at the point they are removed or in piles. Other methods of tie disposal currently in very limited use have the following disadvantages.

1. Air Curtain Destructor
   a. Many states will not allow the use of this method due to the resulting air pollution.
   b. If a mobile destructor is used, pit construction is difficult in some soils.
   c. Transportation and operating costs are high.
   d. Failure of operating personnel to operate according to instructions, creating violations. Strict adherence to manufacturer's recommended practices is necessary for successful operation.
2. Landfill
   a. Transportation and operating costs are high.
   b. Many states require a construction and operating permit.
   c. Land is required.

3. Incineration
   a. Requires a large capital expenditure.
   b. Construction and operating permits are required by air pollution control agencies.
   c. Transportation, operating, and maintenance costs are very high.

4. Tie Chopper
   a. Many states will not permit its use because the chips can float in waterways, plug drainage, release creosote, and cause fires.
   b. Operating costs are high.

5. Sell or Give Ties Away
   a. Ties have to be moved to a location accessible to the public or firm removing them.
   b. Very few people will take ties that have been cut.
   c. Problems of liability due to public on railroad property.

6. Composting
   a. Insufficient research has been done to determine feasibility.

7. Recycling
   a. This would be the most desirable of all the disposal methods since it would result in a usable product. However, too little research has been done on large-scale applications of this method.

3.5.2 Research Needs

(a) The following data will have to be made available before railroads can determine which disposal method is best for a specific location.

1. The actual creosote content of a used tie. Then re-evaluate the acceptability of air curtain destruction, incineration, and recycling as disposal methods.

2. The rate at which creosote is released by used ties to waterways or groundwater when ties are whole or in pieces. Then re-evaluate the acceptability of chipping, landfill, and composting as disposal methods.

3. Cost data showing the optimum size for each of the disposal methods, considering transportation costs and the cost of installing and operating that unit.

4. The extent of the market for used whole and cut ties and determination of the resources which would be required to market them.

5. Using the data from item 1 above, determine what products are likely candidates for used ties as a raw material. Determine the economics of each alternative and then attempt to market the ties in that area.

6. Using the data from all the above, evaluate the whole tie removal procedure, including the disposal method to be used, and determine if it would be more economical to change the method of tie removal currently used. It might, for example, be more economical to remove the ties whole and sell them than to remove them in pieces and incinerate them. It might even be more economical to use different material for tie production and/or preservation.

7. Evaluate the possibility of disposing of the other solid waste resulting from railroad operations in the same disposal system used for tie disposal. It has been estimated that railroads spend over $4,500,000 per year for solid waste disposal exclusive of used ties. If this cost could be eliminated or reduced, the economics of the tie disposal system would be improved considerably.

8. Evaluate the possibility of using ties and solid waste to produce heat or process steam for railroad shops or for sale to outside firms.

(b) Federal research and demonstration grants are available and should be requested to begin the studies enumerated above. However, due to the size of this project, an organization would have to be set up to coordinate the various aspects of this project and funds would have to be provided by the industry. Since this problem is becoming more critical every day and these studies would take several years, it is imperative that it begin as soon as possible.

Report on Assignment 4

Industrial Hygiene

R. S. Bryan, Jr. *(chairman, subcommittee),* W. D. Peters *(vice chairman, subcommittee),* W. H. Melgren, T. A. Tennyson, R. Singer.

Your committee presented in Part 1 of Bulletin 650, November–December 1973, Section 4.5 General Environmental Controls for Sanitation and Industrial Hygiene for Facilities Under FRA Jurisdiction, with the recommendation that it be adopted and published in Part 4, Chapter 13 of the Manual.

Presented below, as information, are Sections 4.6 General Environmental Controls for Air and Noise Pollution for Facilities Under FRA (OSHA) Jurisdiction, and 4.7 Sanitation Requirements for Portable Housing Units.

4.6 GENERAL ENVIRONMENTAL CONTROLS FOR AIR AND NOISE POLLUTION FOR FACILITIES UNDER FRA (OSHA) JURISDICTION

4.6.1

All references shown in Section 4.6 are from Title 29, Chapter XVII, Part 1910, Subpart G, Occupational Health and Environmental Control as published in the *Federal Register,* Vol. 37, No. 202, Wednesday, October 18, 1972. Section 4.6 is intended to be a reference guide for the material covered; the full regulations should be used for specification details. Other specifications which are frequently cited in OSHA are published by the American National Standards Institute (ANSI) and the National Fire Protection Association (NFPA). Latest revisions should always be used.

4.6.2 Ventilation (1910.94).

4.6.2.1 Abrasive Blasting (1910.94 (a)).

(1) Definitions—Respirations, rooms, cabinets, ventilation systems, etc.

(2) Dust hazards from abrasive blasting.

(3) Blast cleaning enclosures.

(4) Exhaust ventilating systems.

(5) Personal protective equipment.

(6) Air supply and compressors.

(7) Operational procedures and general safety.

4.6.2.2 Grinding, polishing and buffing operations (1910.94 (b)).

(1) Definitions applicable to this paragraph.

(2) Every establishment performing dry grinding, dry polishing or buffing shall provide suitable hood or enclosures that are connected to exhaust systems.

(3) Hood and Branch Pipe Requirements—Hoods connected to exhaust systems shall be used and such hoods shall be designed, located, and placed so that the dust or dirt particles shall fall or be projected into the hoods in the direction of the air flow. No wheels, discs, straps or belts shall be operated in such a manner and in such direction as to cause the dust and dirt particles to be thrown into the operator's breathing zone.

(4) Exhaust Systems:

(a) Exhaust systems for grinding, polishing and buffing operations should be designed in accordance with American Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, Z9.2–1960.

(b) These systems shall be tested in the manner prescribed in Z9.2–1960.

(5) Hood and enclosure design—All hoods shall be not less in structural strength than specified in the American National Standard Code for the Use, Care and Protection of Abrasive Wheels, B7.1–1970.

4.6.2.3 Spray Finishing Operations (1910.94 (c)).

(1) Definitions applicable to this paragraph.

(2) Location and Application—Spray finishing operations must be enclosed and shall be located as provided in sections 201 through 206 of the Standard for Spray Finishing Using Flammable and Combustible Materials, NFPA No. 33–1969.

(3) Design and Construction of Spray Booths—See sections 301–304 and 306–310 of the Standard for Spray Finishing Using Flammable and Combustible Materials, NFPA No. 33–1969 for general construction specifications. For a detailed discussion of fundamentals, see ANSI Z9.2–1960.

(4) Design and Construction of Spray Rooms—Spray rooms, including floors, shall be constructed of masonry, concrete or other noncombustible material.

(5) Ventilation—See Chapter 5 of the Standard for Spray Finishing Using Flammable or Combustible Materials, NFPA No. 33–1969.

(6) Velocity and Air Flow Requirements—See Table 10-G, Minimum Maintained Velocities Into Spray Booths in 1910.94 (c) of OSHA Regulations.

(7) Make-up Air—Clean, fresh air, free of contamination from adjacent industrial exhaust systems, chimneys, stacks or vents shall be applied to a spray booth or room in quantities equal to the volume of air exhausted through the spray booth or rooms.

(8) Scope—Spray booths or spray rooms are to be used to enclose or confine all spray operations covered by 1910.94 (c). It does not apply to the spraying of exterior buildings, fixed tanks or similar structures, nor to small portable spraying apparatus not used repeatedly in the same location.

4.6.2.4 Open Surface Tanks (1910.94 (d)).

(1) General—This paragraph applies to all operations involving the immersion of materials in liquids, or in vapors of such liquids, for the purpose of cleaning or altering the surface or adding to or imparting a finish thereto or changing the character of the material, and their subsequent removal from the liquid or vapor, draining and drying. The operations include washing, electroplating, anodizing, pickling, quenching, dyeing, dipping, tanning, dressing, bleaching, degreasing, alkaline cleaning, stripping, rinsing, digesting and other similar operations.

(2) Classification of Open Surface Tanks—Open surface tank operations shall be classified into 16 classes, numbered A-1 to D-4, inclusive, determined by two factors. Hazard potential designated by a letter from A to D and the rate of gas, mist or vapor evolution designated by a number 1 to 4. Tables G-12 and G-13 of 910.94 (d) must be used to determine classification.

(3) Ventilation—Where ventilation is used to control potential exposures to workers, it shall be adequate to reduce the concentration of the air contaminant to a degree that a hazard to the worker does not exist. Methods of ventilation are discussed in American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems Z9.2–1960.

(4) Control Requirements—Control requirements shall conform to Table G-14 in 910.94 (d) in all cases where the flow of air past the breathing or working zone of the operator and into the hoods is undisturbed by local environmental conditions, such as open windows, wall fans, unit heaters or moving machinery. All tanks exhausted by means of hoods which do not project over the entire tank, and in which the direction of the air flow into the hood or hoods is substantially horizontal, shall be considered to be laterally exhausted. The quantity of air in cubic feet per minute necessary to be laterally exhausted per square foot of tank area shall be determined by Table G-15 of 910.94 (d).

(5) Spray Cleaning and Degreasing—All such operations shall be enclosed.

(6) Control Means Other Than Ventilation—Tank covers, foams, beads, chips or other materials floating on the tank surface so as to confine gases, mists or vapors under cover, or surface tension depressants added to the liquid in the tank to minimize mist formation, or any combination thereof may be used if they effectively reduce the concentration of the hazardous material below the acceptable concentration level.

(7) System Design—The exhaust system, consisting of hoods, ducts, air mover and discharge outlet shall be designed in accordance with American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems Z9.2–1960.

(8) Operation—The required airflow shall be maintained at all times during which gas, mist or vapor is emitted from the tank, and at all times the tank, the draining or the drying area is in operation.

(9) Personal Protection—All employees working in and around open-surface tank operations must be instructed as to the hazards of their respective jobs and in the personal protection and first aid procedures applicable to these hazards.

(10) Special Precautions—Certain chemicals are particularly hazardous and all special precaution applying to that chemical must be followed in addition to ordinary precautions.

(11) Inspection, Maintenance and Installation—Floors and platforms shall be prevented from becoming slippery both by original type construction and frequent flushing. Before cleaning the interior of any tank, the contents shall be drained off and the cleanout doors opened. Tank must be ventilated and cleared of vapors. All other normal precautions should be observed when cleaning, repairing or welding in these areas.

(12) Vapor Degreasing Tanks—In any vapor degreasing tank equipped with a condenser or vapor level thermostat, the condenser or thermostat shall keep the level of vapors below the top edge of the tank by a distance at least equal to one-half the tank width, or at least 36 inches, whichever is shorter.

4.6.3 Occupational noise exposure (1910.95)

4.6.3.1 Protection Against Exposure.

(1) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G-16 when measured on the A scale of a standard sound level meter at slow response.

TABLE G-16

Duration Per Day Hours	*Sound Level dBA Slow Response*
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

(2) When employees are subjected to sound exceeding those listed in the above table, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the above table, personal protective equipment shall be provided and used to reduce sound levels to the levels of the table.

(3) In all cases where the sound levels exceed the values in the table, a continuing, effective hearing conservation program shall be administered.

(4) Exposure to impulsive or impact sound should not exceed 140 dBA peak sound pressure level.

4.7 SANITATION REQUIREMENTS FOR PORTABLE HOUSING UNITS

4.7.1 General

(a) The term "Portable Housing Unit" or "Portable Accommodation Unit" covers all self-contained living accommodations which can be readily lifted from the deck of a flatcar or any other temporary foundation.

(b) Portable housing units should be inspected every six months under a preventive maintenance schedule. This schedule should include the electrical system, the water and sewage disposal systems, all appliances, heating systems, the general condition of the unit as well as good housekeeping practices.

4.7.2 Utilization of Units

(a) Units are to be kept clean and tidy, floors are to be washed at regular intervals, particularly around appliances. All washing facilities are to be kept in a clean and sanitary condition and grating at shower stalls must be cleaned periodically.

(b) Burning cigarettes ancd matches must not be placed or extinguished on counter tops or linoleum floors, as damage will result. "USE ASH TRAYS."

(c) Under no circumstances must burning matches, cigarettes or ashes be deposited in recirculating flush-type chemical toilets. These units are constructed of ABS plastic material and will become easily damaged, causing inefficient operation of the unit.

(d) Do not deposit paper towels, wet-strength tissue paper or other articles in toilets. Use toilet tissue only. These units are equipped with a self-cleaning filter and will become clogged if other types of paper are used.

(e) If toilets other than recirculating flush-type chemical toilets are used, follow the instructions issued with the toilet unit.

(f) All refuse must be placed in covered receptacles provided.

(g) Each employee is responsible for maintaining his quarters in a clean and tidy condition.

4.7.3 Sanitation

4.7.3.1 General

(a) It is imperative that the area around all housing units be kept clear of all refuse and sewage. In no way is it permissible to drain sewage on the ground between or adjacent to the tracks.

(b) Cleanliness and sanitary conditions must always be maintained around toilet and wash facilities.

(c) The person in charge of the housing units should be responsible to ensure that sanitary regulations are strictly adhered to.

(d) Local regulations must be met with regard to disposal of all waste, garbage and drainage of water and sewer lines.

4.7.3.2 Drinking Water

(a) Water for human consumption must be obtained from a source approved by health authorities. Water obtained from a *doubtful source,* such as wells, lakes and rivers must be chlorinated. A simple method of water purification is as follows: Add 1 ounce of commercial bleach solution (5.25% sodium hypochlorite) to 5 U.S. gallons of water *or* one 5-grain Halazone tablet to 4 U.S. gallons of water. If Halazone tablets are used, allow one-half hour for purification period due to tablet dissolving slowly.

(b) *Water Containers and Systems for Drinking Water and Culinary Purposes:* All containers used for this purpose shall be tightly covered and provided with a tap outlet. They shall be sterilized once a week, or more often, if necessary by filling the container and adding 1 ounce of commercial bleach for a 5-gallon container; 10 ounces will sterilize a 50-gallon container. Closed water systems equipped with filters require flushing and sterilization annually; systems with no filters require flushing and sterilization every three months or more often if contamination is suspected. Individual disposable cups and dispensers shall be provided and used for drinking water. *Common drinking cups or dippers are prohibited.*

4.7.3.3 Refrigerators

(a) Ice boxes should not be used unless essential, and when used shall be emptied and washed out weekly with a sterilizing solution. Electric refrigerators shall be emptied, defrosted and washed out once a month. (Use 1 teaspoonful of chlorox to 1 ounce of detergent-bactericide in a 1½-gallon pail of hot water.) An open container of baking soda placed in refrigerators will assist in odor control and should be replaced each month. In case of a breakdown, it is essential perishable foods be obtained on a day-to-day basis, particularly in warm weather.

4.7.3.4 Dishes and Utensils

(a) After each meal, all dishes, utensils and equipment shall be washed and sterilized using 1 ounce of detergent-bactericide powder to 1 gallon of hot water in a sink filled with hot water. Change water every 30 minutes. Cracked or chipped dishes and damaged table utensils shall not be used and are to be replaced. Clean dishes shall be stored in an enclosed cabinet above floor level.

4.7.3.5 Insect Control

(a) It is essential that all kitchen, dining, food storage and personal wash areas be kept free of flies, cockroaches and other insects. All doors, windows, and roof vents shall be properly screened and screen doors kept securely closed. A sufficient supply of insecticide and spray containers shall be kept on hand. Use of vapour strips is not recommended.

4.7.3.6 Cleaning of Kitchen, Dining, Food Storage and Personal Wash Areas

(a) Floors are to be swept and washed each day. All table tops in food and dining areas shall be covered with a smooth, seamless, impervious material and shall be washed following each meal using 1 ounce of chlorox to 1 U.S. gallon of hot water. Shelving and cupboards shall be maintained in a clean and orderly condition at all times. The use of food and vegetables storage bins shall be eliminated. Food preparation areas surrounding cook stoves are to be thoroughly cleaned and kept free from food spills, grease accumulations, etc. Foods shall be removed from tables following each meal and not replaced until 20 minutes before the next meal serving time. *Any food that is unfit or of a suspicious nature is to be condemned and replaced.* The walls of all kitchen and dining areas shall be washed down a minimum of every six months and more frequently if required, using ½ cup chlorox to 1 U.S. gallon of hot water.

4.7.3.7 Personal Cleanliness

(a) Cooking and food-handling personnel shall wash their hands thoroughly with hot water and soap before starting work and after each visit to the toilet. Signs shall be posted to this effect. Cooks and all food-handling personnel shall wear clean, white clothing and aprons and shall carry current medical cards.

4.7.3.8 Garbage and Waste Disposal

(a) Polyethylene or plastic bags shall be supplied and used as garbage pail liners and shall be disposed of in accordance with local regulations, or by burying in a covered garbage pit where permitted. A garbage pit shall be prepared (where permitted) and located not less than 100 ft from the kitchen car. When the gang moves, covers will be removed and pits filled completely with earth. All liquid waste water shall be removed by approved drainage hoses or pipes to municipal sewers, where available, or to prepared sump pits, covered, located not less than 50 ft from any gang car or unit. When this method is used, sump pits are to be completely filled and covered with earth when the gang moves.

4.7.3.9 Toilets

(a) *Recirculating Toilets* in portable accommodation units and other equipment shall be given a thorough cleaning and recharging every 5 to 8 days, or when liquid appears in the bottom of the bowl. To empty the recirculating toilet: (1) ensure drainage piping to sewer or sump pit is properly attached to exterior toilet drains; (2) open the valve after removing the front skirt; (3) allow waste to thoroughly drain through drainage hose or pipe to sewer, sump pit, or tank truck; (4) open and close valve as required to rinse thoroughly and flush system several times using clean water; (5) close valve and replace skirt; (6) pour three measured gallons of water into toilet bowl, press flush button and add deodorant-bactericide, in accordance with manufacturers instructions, into bowl while it is flushing. Once recharged, it will operate effectively for approximately 80 usages over a 5- to 8-day period. Care is to be exercised to ensure that overfilling in the recharge routine above does not occur, causing damage and malfunction of the toilet. *Whether pit privies or sump pits for recirculating toilets are used, extreme caution is to be exercised to ensure that pollution of any water course or well does not occur.*

(b) If other type toilets are used, they must be in compliance with local health and sanitary regulations.

4.7.3.10 Bunk Cars and Accommodation Units

(a) All areas shall be kept in a neat and tidy condition at all times. The floors shall be swept and washed a minimum of once per week or more frequently if required. All windows shall be screened. All units and bedding shall be aired regularly, preferably once per week. Outside work clothing should not be kept or hung in sleeping areas, but should be kept in areas provided for this purpose. In portable accommodation units, the summer circulating fan system is to be used at all times in warm weather. The hanging of washing in rooms or sleeping areas is prohibited. All washing is to be hung only in areas provided for this purpose. All windows shall be thoroughly washed inside and out a minimum of twice yearly.

4.7.4 Shut-Down of Units

(a) If units are to be shut-down for any lengthy period, the following steps should be taken:

1. Drain all toilets and flush thoroughly.
2. Drain *all* water systems in all type units.
3. Open all faucets at sinks and showers.

Report of Committee 15—Steel Structures

L. F. Currier, *Chairman*

D. S. Bechly,
Vice Chairman

J. M. Hayes, *Secretary*

D. L. Nord
W. D. Wood
F. P. Drew
C. A. Hughes
J. G. Clark
R. I. Simkins

H. A. Balke
J. E. Barrett
L. S. Beedle
J. Berger
L. N. Bigelow
E. S. Birkenwald (E)
E. Bond
T. J. Boyle
J. C. Bridgefarmer
C. J. Burroughs
H. L. Chamberlain
R. W. Christie
J. S. Cooper
H. B. Cundiff
E. J. Daily
A. C. Danks
J. W. Davidson
L. D. Davis
R. P. Davis (E)
E. B. Dobranetski
J. L. Durkee
N. E. Ekrem
J. W. Fisher
G. F. Fox
G. K. Gillan
C. E. Gilley
J. W. Hartmann
A. Hedefine
G. E. Henry
L. R. Hurd
R. D. Hutton
M. L. Koehler
L. R. Kubacki
A. Lally
E. M. Laytham
K. H. Lenzen
A. D. M. Lewis
H. B. Lewis
R. C. McMaster
D. V. Messman (E)
J. Michalos
G. E. Morris
R. H. Moulton
V. V. Mudholkar
W. H. Munse
R. D. Nordstrom
W. H. Paihl, Jr.
A. L. Piepmeier
R. G. Pierides
J. H. Powers
W. W. Sanders, Jr.
M. Schifalacqua
A. E. Schmidt
F. D. Sears
G. R. Shay
H. Solarte
A. P. Sousa
J. E. Stallmeyer
Z. L. Szeliski
J. D. Tapp, Jr.
W. M. Thatcher
E. S. Thoden
R. N. Wagnon
C. R. Wahlen
R. H. Wengenroth
W. Wilbur
E. N. Wilson
A. J. Wood
M. O. Woxland
J. A. Zeleznikar
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Revisions to Specifications for Steel Railway Bridges submitted for adoption were published in Part 1 of Bulletin 650, November–December 1974.

1. Develop Criteria for the Design of Unloading Pits, Collaborating with Committees 7 and 8.
No report.

2. Obtain Data from Which the Frequency of Occurrence of Maximum Stress in Steel Railway Bridges May Be Determined Under Service Loading.
No report.

3. Protection of Steel Surfaces.
No report.

7. Bibliography and Technical Explanation of Various Requirements in AREA Specifications Relating to Steel Structures.
   No report.

10. Continuous Welded Rail on Bridges, Collaborating as Necessary or Desirable with Committee 4.
    A new Section 8.3 of the Specifications for Steel Railway Bridges, entitled "Anchorage of Decks and Rails on Steel Bridges" was submitted for adoption and was published in Part 1 of Bulletin 650, November–December 1974.

THE COMMITTEE ON STEEL STRUCTURES,
L. F. CURRIER, *Chairman.*

Report of Committee 27—Maintenance of Way Work Equipment

F. H. Smith, *Chairman*

C. H. Olds,
Vice Chairman

D. D. Fisher
W. A. MacDonald
J. P. Zollman
V. R. Erquiaga
W. F. Cogdill

D. E. Crawford
M. L. Stone
P. V. Divine
W. J. Gottsabend
E. T. Daley

R. W. Bailey
L. J. Calloway
L. E. Conner
R. E. Dove
R. P. Drew
J. M. Driehuis
H. F. Dully
J. O. Elliott
V. L. Emal
E. H. Fisher
W. D. Gilbert
W. J. Gilbert
R. E. Gorsuch
O. T. Harmon, Jr.
S. R. Horn
N. W. Hutchison (E)
C. Q. Jeffords
R. M. Johnson
J. Kelly
M. E. Kerns (E)
C. F. King
W. F. Kohl
W. E. Kropp (E)
H. F. Longhelt
G. J. Lyon
R. L. Matthews
C. E. McEntee
R. Million
A. E. Morriss, Jr.
R. E. Murdock
C. A. Peebles
J. R. Pollard, Jr.
J. E. Quirk
R. S. Radspinner
D. F. Richardson
R. H. Richmond
B. F. Riegel
T. R. Rigsby
J. W. Risk (E)
R. T. Ruckman
D. R. Schenck
D. Schulz
J. T. Smith
S. E. Tracy (E)
C. R. Turner
J. L. Van Meter
S. W. Walker
N. White
J. W. Winger

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

1. Reliability Engineering as Applicable to Work Equipment Design and Manufacture.
No report.

2. Machine Design—Hydraulic and Electrical Systems.
No report.

3. Machine Design—Engines.
Progress report presented as information .... page 354

4. Machine Design—Drive Train, Including Clutch, Transmission, Final Drive and Power Take-Offs.
No report.

5. Machine Design—Bearings, Suspension, Frame and Brakes.
No report.

6. Study Design of Cars Used by Maintenance of Way Department, Such as Ballast Cars, Equipment Transport, Tie Cars, Rail Cars, Etc.
No report.

7. Temperature Compensated Stress-Adjustment Equipment for Use During or After Laying CWR, Collaborating as Necessary or Desirable with Committee 4.
No report.

8. Actual Cost to Operate a Piece of Work Equipment.
No report.

9. Data Processing for Work Equipment Evaluation, Information and Control, Collaborating as Necessary or Desirable with Committee 32.
No report.

10. Applied Metallurgy—Maintenance of Way Work Equipment.
No report.

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
F. H. SMITH, *Chairman.*

Report on Assignment 3

Machine Design—Engines

V. R. ERQUIAGA *(chairman, subcommittee)*, D. E. CRAWFORD, E. T. DALEY, D. D. FISHER, W. J. GOTTSABEND, W. A. MACDONALD, R. L. MATTHEWS, C. R. TURNER.

Your committee submits the following data as information and for guidance in the selection of engines for maintenance of way work equipment.

In order to obtain maximum efficiency, performance and economy in the operation of roadway maintenance equipment, it is of utmost importance that selection of engines be made with care. Each type and size of engine is designed to provide optimum performance and economy under specific conditions. Proper engine applications are essential to maintenance of satisfactory production capabilities and costs.

GASOLINE ENGINES VERSUS DIESEL ENGINES

The major advantages of using a gasoline engine in lieu of a diesel engine are:

(a) The gasoline engine is relatively lighter in design, has less weight per horsepower.
(b) Lower parts cost.
(c) Initial cost is somewhat lower.
(d) Generally speaking, parts availability is better.
(e) Better fuel availability.
(f) Gasoline engine testing can be performed with relatively inexpensive tools and equipment.
(g) The gasoline engine can attain higher rpm speeds efficiently.
(h) In cases where hand-cranking is required, the gasoline engine is easier to start with lower cranking effort.

(i) Mechanics require less training to maintain gasoline engines, and mechanics are more readily available.
(j) Wide variation obtainable in speed and load factors.
(k) High mechanical efficiency and fairly low specific fuel consumption at high compression and full throttle.

Most suitable job applications for gasoline engines are:

(a) In applications where smaller engines of 100 hp or less are required.
(b) Where utilization is limited to no more than 1,000 hours per year.
(c) Where weight is a critical factor.
(d) Where higher rpm's and intermittent power requirements are needed.

The major advantages of the diesel engine over the gasoline engine are:

(a) Longer operation between overhauls.
(b) Less day-to-day service required.
(c) Requires less fuel per horsepower output.
(d) More reliable.
(e) A more constant power source.
(f) Not affected as much by weather conditions.
(g) Lower rate of air pollution.
(h) Low rate of contamination at idle speeds.
(i) Less susceptible to vandalism.
(j) Higher torque capabilities.
(k) Less fire hazard.
(l) Longer overall life expectancy.
(m) Less prone to be tinkered with.
(n) Rebuilding can be accomplished many times.
(o) Less fuel pilferage potential.
(p) Good thermal efficiency at partial loads.
(q) Not as many electrical problems.
(r) Fuel cost less.
(s) No pre-ignition, no CO except at full load or overload.
(t) Suitability for two-cycle operation.

Job applications that are most suited for the diesel engine are:

(a) Where maximum power requirements are needed.
(b) Where steady rpm requirements prevail.
(c) In applications where maximum performance over extended periods is required.
(d) Economies accelerate greatly in applications in excess of 100 hp.
(e) Underground operations.
(f) In operations where machine benefits from lower rpm range for maximum horsepower to torque.

Naturally Aspirated Versus Supercharged or Turbocharged Engines

Turbocharging has become the most popular method of supplying additional air or (blowing) engines. The blown engine has advantages over the naturally aspirated engine as follows:

A blown engine will produce as much horsepower as a naturally aspirated engine having 50% greater cubic inch displacement. This is to say, of two engines of the same make and size, one naturally aspirated, one turbocharged, the turbocharged engine will produce 50% more horsepower. A smaller engine producing comparable horsepower to the larger displacement engine will cost approximately 25% less than the larger engine.

The advantage of the larger displacement naturally aspirated engine is realized in applications where a drive through solid gear box or direct solid drive is required. The naturally aspirated engine will recover more quickly as it has the advantage of higher torque from dead start. This is because the turbocharger must turn up required rpm's before it becomes effective. On the other hand, when automatic transmissions, converters, etc., are used in the drive mechanism, they permit the engine to rev up sufficiently for turbocharger to operate efficiently.

We must not be misled, however, in believing that all that is necessary is to apply a turbocharger to any engine and realize the advantages listed. The particular engine must be designed to withstand the added pressures within cylinders, bearings, etc., resulting from turbocharging, and must have proper design in valve cooling to withstand added heat factors. If engine is not designed properly, premature engine failures and expensive repairs and downtime can be expected. For example, a naturally aspirated engine rated at 200 hp must be engineered and designed throughout to withstand the pressures to put out 300 hp in order that turbocharger can be applied successfully.

Originally, many problems were encountered with turbochargers, especially with bearings and seals. However, present day turbochargers have been improved to a point where very satisfactory service can be expected. However, consideration must be given to the fact that the turbocharger is an additional sub-system to the engine package which requires maintenance and attention.

Liquefied Petroleum Gas (LPG) Engines

The characteristics of the LPG engine are very similar to those of the gasoline engine, the differences being gaseous versus liquid fuel and the entry of fuel into the intake manifold in these forms. The LPG engine has limited advantages over both the diesel and gasoline engine:

(a) The LPG has a relatively longer life expectancy than the gasoline engine and comparable to the diesel.
(b) No fuel pump required.
(c) The production of combustion is less toxic.
(d) Close control of fuel-air ratio and clean burning with complete combustion.
(e) Exhaust is very clear.
(f) Crankcase contamination is relatively small.

The principal disadvantages of the LPG engine are the necessity of closely supervised, careful fuel handling and limited fuel availability.

Some of the most suitable applications for the LPG engine are:

(a) Inside building operations.
(b) Tunnel work.
(c) Standby generator service.
(d) Forklifts and shop tractors operating in confined areas.
(e) Constant operation in cities badly affected by smog.

TWO-CYCLE VERSUS FOUR-CYCLE DESIGNS

In selecting an engine, consideration should be given to the two- or four-cycle design. Advantages and disadvantages lie with each type, for example:

Two-Cycle Engine:

(a) Offers more power per size of engine, 50 to 80% greater horsepower output per unit piston displacement and speed.
(b) Less weight per horsepower.
(c) Quicker starting with less cranking force.
(d) Lower derating values for altitude increases.
(e) Lower cost design.
(f) Faster acceleration qualities.

On the other hand, the four-cycle engine offers advantages as follows:

(a) Longer life expectancy.
(b) Lower operating noise level than the two-cycle engine.
(c) Fuel consumption less per horsepower.
(d) Greater range in horsepower operation.
(e) More efficient under lighter loads.
(f) Lower peak firing pressures.
(g) A more constant power stroke.
(h) Fuel system requires less adjustment.
(i) Less offensive exhaust odor.
(j) Wide variation in speed or load factor.
(k) Good lubrication secured more easily.

RATIO OF ENGINE HORSEPOWER TO ACTUAL POWER REQUIRED

Another item of great importance in selecting a power source is the ratio of engine horsepower to actual power required:

(a) The only advantage of underpowering is lower first cost. Underpowering results in an overworked engine, heavy repair costs, high fuel consumption, premature overhauls and poor performance.
(b) Overpowering in excess will result in poor thermal efficiency, a dirty engine, high fuel costs and relatively short engine service life.
(c) The following reflects recommended overpowering in order to obtain maximum efficiency, economy and service life:

Engine Type	*Overpower at Sea Level*	*Additional Per Each 1,000 Ft Elevation*
1. Gasoline	30%	3½%
2. Propane	30%	3½%
3. 4-cycle naturally aspirated diesel	30%	3½%
4. No. 3 equipped with turbocharger	30%	None
5. 2-cycle blower scavenging naturally aspirated diesel .	30%	2.30%
6. No. 5 equipped with turbocharger	30%	None

In regard to Item 2, in the event a gasoline engine is converted to propane, a 15% loss in horsepower from its original rating can be expected.

In making a conversion, use of manufacturer's specified conversion kit is recommended.

SOLID ENGINE BLOCK VERSUS SLEEVE-TYPE ENGINE BLOCK

Still another factor which should be considered in selecting an engine is the solid engine block versus sleeve type engine block:

The solid block design offers advantages in that:

(a) It incurs less warpage.
(b) Has less chance of water leaks.
(c) Better cooling characteristics.
(d) Generally lighter in weight per horsepower than sleeve block.
(e) Lower cost to manufacture.
(f) Smaller number of parts to assemble.

On the other hand, the sleeve block can:

(a) Be overhauled practically an indefinite number of times.
(b) Can be maintained at standard cylinder sizes.
(c) Greater simplicity in major overhaul work—possible in the field.
(d) More economical to overhaul.

TRANSMISSION FACTORS

When selecting an engine, consideration should be given to type of transmission being used.

Automatic/hydraulic transmissions are advantageous in some operations in that:

(a) They lend themselves to short-range workable power with engines developing most efficient power at 1500 to 2000 rpm's.
(b) Automatics take the gear shifting out of the operator's hands.
(c) Normally, automatic transmissions permit engines to operate at more constant speed.

Some disadvantages of the automatic transmissions are:

(a) Initial cost considerably more.
(b) Requires greater skill on the part of mechanics to overhaul and repair.

Regardless of what type of transmission is used, the engine/transmission combination should be governed by the following:

(a) Transmission must be rated to handle the maximum torque produced by the engine, braking or backlash.
(b) Transmission must be able to provide sufficient number of ratios to keep engine operating in its designed rpm range.
(c) Engine/transmission combination must provide an adequate speed and torque output for all machine operating requirements.

WATER-COOLED VERSUS AIR-COOLED ENGINES

In the event a choice between water-cooled and air-cooled engine is offered, the air-cooled engine has the advantage of:

(a) Being lighter in weight per horsepower.
(b) Requires less room.
(c) Lower initial cost.
(d) Elimination of coolant system maintenance.

The advantages of the water-cooled engine are:

(a) Can operate under dirty conditions more efficiently.
(b) Water jackets provide more even cooling.

(c) Less detrimental effects operating in high temperatures.

(d) Longer economical service life.

(e) Much better thermal efficiency because of the possibility of controlling engine temperatures as required with use of water, fan and thermostat mediums of control.

(f) Work much more efficiently with varied loads because of temperature controlling capability.

SAFETY CONTROLS

Safety controls are recommended for engines of 50 hp or more which may operate unattended. These controls stop the engine in the event low oil pressure or high water temperature is encountered. They offer inexpensive protection against costly damage to expensive engines. Some applications for smaller engines may also warrant use of these controls. Where operator is present, an alarm system is preferred over automatic control, particularly where engine might be shut down at an unsafe or unsatisfactory point in equipment work cycle, as in the case of a hoisting crane with a raised near-capacity load.

HOUR METERS

Hour meters are very helpful in the maintenance and operation of engines:

(a) They can be used to a great advantage if a regular maintenance program is being followed.

(b) If engines are operated at average operating speeds, hour meters can be used to measure the maintenance cycle as well as record actual hours operated.

(c) RPM gear-driven meters are not necessarily related to actual clock hours. If engine is operated at approximately 1600 rpm's, meter will then relate closely to a time clock.

OIL FILTERS

The most suitable type of oil filter is the cartridge replacement unit type. The full-flow with relief valve is most efficient. The manufacturer of the respective engines should approve the type of oil filter used. The addition of oil filters can restrict oil flow to bearings, etc. Accordingly, manufacturer's specifications should be closely adhered to.

AIR CLEANERS

Air cleaners are of three general types: (1) dry type, (2) oil bath type, (3) combination. In addition, cleaners may be one, two or more stages of varying designs. They should be carefully selected to:

(a) Provide best possible service under equipment operating conditions in the field.

(b) Provide an adequate service interval and service cost.

(c) Make proper service as simple as possible.

Engine life is directly related to the amount of dirt that enters the engine; therefore, the best possible cleaner is a good investment.

Any gravity fed engine must have a screen type filter. Any engine with pressurized fuel system must have a filter in the fuel line.

Report of Committee 28—Clearances

M. E. Dust, *Chairman*

L. Schmitz,
Vice Chairman

J. E. Beran, *Secretary*

R. T. Pritchett
L. R. Beattie
E. E. Kessler
W. S. Tustin
F. A. Svec
G. J. Adams
P. T. Sarris

E. Berendt
E. S. Birkenwald (E)
D. H. Brown
G. M. Buck
R. P. Christman
J. E. Cosky
J. A. Crawford
S. M. Dahl (E)
C. W. Farrell
C. A. Gerstner
G. E. Henry
J. C. Hobbs
C. A. Hughes
G. P. Huhlein
L. R. Hurd
C. F. Intlekofer
E. W. Jantz
O. H. Jensen
J. L. Kampwirth
R. G. Klouda
A. J. Kozak
D. W. LaPorte
E. C. Lawson
G. W. Martyn
A. E. Mooney
J. R. Moore
W. E. Morgus
M. D. Murphy
F. B. Persels
C. E. Peterson (E)
M. L. Power
E. C. Smith
R. R. Snyder
C. H. Stephenson
J. E. Teall
W. J. Trezise
M. Van Kuiken
M. E. Vosseller

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Recommendation that Chapter 28 of the Manual be reorganized into a decimalized format was submitted for adoption and was published in Part 1 of Bulletin 650, November–December 1974.

1. Investigate the Practicability of Using Disposable Coded Placards for Identifying Shipments of Excessive Dimension and/or Weight that Could Be Used in Conjunction with the Automatic Car Identification System.
No report.

2. Compilation of the Railroad Clearance Requirements of the Various States.
A tabulation of the state legal requirements was submitted for adoption and was published in Part 1 of Bulletin 650, November–December 1974.

3. Investigate new Methods and Development of Equipment for Recording Measurements of Clearances of Structures Along Right-of-Way and Overall Dimensions of Cars and Loads.
No report.

5. Revise "Suggested Method of Presenting Published Clearances" now in the Manual.
   No report.

8. Extend "Table for Computing Curve Offsets on Overhanging Loads," now in the Manual, to Accommodate Longer Loads and Longer Truck Centers, Collaborating as Necessary or Desirable with Committee 32.
   Revised and extended tables were submitted for adoption and were published in Part 1 of Bulletin 650, November–December 1974.

9. Investigate the Possibility of Including the Truck Center Dimension of All Cars in the Official Railway Equipment Register, Collaborating as Necessary or Desirable with the Mechanical Division, AAR.
   No report.

THE COMMITTEE ON CLEARANCES,
M. E. DUST, *Chairman.*

Report of Committee 32—Systems Engineering

R. H. Knittel, *Chairman*

R. W. Holt,
Vice Chairman

B. W. H. Jaeger,
Secretary

R. B. Sliepka,
Co-Secretary

A. W. Polich
R. P. Howell
D. L. Glickstein

H. R. Williams
A. D. M. Lewis
S. K. Kauffman
R. E. Tuve

R. E. Ahlf
R. S. Allen
E. R. Andrlik
R. W. Bailey
H. J. Bellows
D. R. Bergmann
F. T. Berry
R. J. Berti
W. R. Bjorklund
J. R. Boyer
A. P. Campbell, Jr.
H. L. Chamberlain
R. D. Combs
J. E. Cosky
K. Cotten
F. A. Daly
A. V. Dasburg
J. F. Davison
L. P. Diamond
R. Dirvonis
R. L. Ealy
F. C. Edmonds
D. J. Faulkner
E. H. Fisher
F. D. Free
A. J. Gellman
R. C. Gilbert

L. F. Grabowski
A. M. Handwerker
D. M. Harlan
R. W. Hope
M. Horn
R. H. Johnston
S. M. Jones
R. G. Klouda
M. W. Krug
R. A. Lathrop
C. E. Law
J. F. Lynch, Jr.
G. F. McGlumphy
D. A. Meizys
A. B. Merritt, Jr.
H. L. Murphy
K. S. Niemond
M. Noyszewski
B. H. Price, Jr.
R. P. Rasho
F. G. Schurman
R. M. Soberman
J. J. Stark, Jr.
H. E. Storey
R. L. Sumner
T. W. Toal
M. Velebit
E. N. Wilson
C. F. Wiza
J. R. Wood, Jr.
T. P. Woll
A. Youhanaie
Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Manual and Revision of Manual.
No report.

1. Define Systems Engineering and Illustrate Systems Concepts with Applications to Railroad Engineering.
No report.

2. Administrative Systems—Disseminate Information Pertinent to Design and Implementation, Including Specific Applications or Techniques Within the Scope of Railroad Engineering.
Progress report, presented as information .... page 364

3. Technical Applications—Disseminate Information Pertinent to the Design and Implementation of Computer Solutions to Specific Engineering Design and Analysis Problems.
No report.

4. Compile a Digest of Present Railroad Engineering Systems Applications, Including all Present Systems-Oriented Applications of the Assignments of Other AREA Committees.
   No report.

5. Systems Engineering Education—Collect and Disseminate Information to the Association Membership by Means of Special Features, Seminars, Demonstrations and Printed Material.
   Progress report, presented as information .... page 368

6. Provide Interface for Coordination of Effort in Railroad Engineering Systems.
   No report.

The Committee on Systems Engineering,
R. H. Knittel, *Chairman.*

Report on Assignment 2

Administrative Systems—Disseminate Information Pertinent to Design and Implementation, Including Specific Applications or Techniques Within the Scope of Railroad Engineering

R. P. Howell
Chairman, Subcommittee

Your committee presents as information the following paper describing the steps taken by the New York City Transit Authority to improve the management of its stores operations.

NEW YORK CITY TRANSIT AUTHORITY STORES OPERATIONS

By STEVEN K. KAUFFMAN[1] AND BARRY G. COX[2]

The subway system in New York City moves nearly 4 million passengers each day, runs 7,000 trains each day, and employs nearly 30,000 people. By any measure, the New York City Transit Authority subway operation is larger than any other in the country. This presents special problems, but it also presents special opportunities. One of the opportunities was presented when the impact on performance of an austere material budget policy became apparent a few years ago.

In 1970 the on-time performance of the subway system was under 80% and the number of trains unavailable for the morning rush hour was peaking at 110. The deteriorated condition of the car fleet had to be improved, and it became obvious that one of the factors had to be a massive infusion of parts into the stores inventory. A shortage of parts was one of the major culprits in causing the lack of reliability and, in turn, the delays in service and poor on-time performance. The unavailability of most of the 100 trains for morning service could also be blamed on parts shortages.

---

[1] Executive Assistant.
[2] Transit Management Analyst.

Material reorder policies were established which dramatically increased parts availability. However, the value of the inventory ballooned at the same time. The decision to start this massive infusion into the inventory was necessitated by two factors:

(1) As mentioned above, the economy measures necessitated by heavy operating losses had cut the inventory so that new parts could not be put onto the cars when they were needed.

(2) Because of the liberal retirement policy, started in 1968, the skill and experience level of Transit Authority maintenance employees dropped. The material-related effect of this was that the new employees did not have the skill to dress up old parts so that they could be reused. They had to have new parts to restore the cars to serviceable condition.

In addition to the major increase in inventory, the Authority took other steps to improve reliability and availability. We established major overhaul programs, increased the maintenance staff and purchased some new cars.

At the time all this was going on, steps were being taken to improve the management of the stores inventory. Research into material support policies, practices, and procedures culminated in the reorganization of the staff performing material-control functions, the tightening of existing procedures, and the introduction of the most modern management systems and controls available. To implement such programs, a responsible and experienced material control manager was needed. S. J. Conrad, a man with over 20 years of experience in supply management and material systems as a Navy supply officer, was placed in charge of the stores operation. Mr. Conrad is the key to the efficient operation of the New York City Transit Authority Stores System.

The stores operation of the Transit Authority has the responsibility of assuring material availability of over 100,000 line items of material for repair and upgrading of the Authority's rolling stock and line equipment. The goal is maximization of service to users and minimization of total costs. Stores management tries to maintain the best balance between the level of availability of parts and the cost of achieving that level of availability. The costs include inventory carrying costs.

The first step in the research effort to improve the management of the inventory was to perform an analysis of the stratification of the inventory by dollar-use. This is commonly known as an ABCD Analysis. Computer runs were made to range active items in order of descending annual dollar-value of usage and inactive items in order of descending value of inventory. "A" items constitute those items which account for 50% of the dollar-value of usage (stores issues) during one year. The "B" items were the next 30%, "C" items the next 15% and "D" items the bottom 5%. The "E" items were items in inventory which had no movement during the year, and the "F" items were those items for which there was not only no movement, but no inventory. For the most part, the "F" items were just taking up space on the computer file.

As a result of this analysis, it became apparent that less than 600 line items accounted for more than 50% of the value of material used during the year. A program called "SIMS" (Selective Item Management System) was immediately started to manage those 600 items. By concentrating high-quality management on less than 1% of the line items in our inventory, we immediately were able to make significant improvements in what amounts to half of our "Sales." Mr. Conrad personally assumed the responsibility for this management function, a task which takes about 10% of his time. He will eventually pass this on to a qualified subordinate.

After the decision had been made to start using SIMS, the next step was to begin development of a management system to apply the same high-quality administration to the entire inventory.

(A) A unique system of determining minimum stock levels was begun in cooperation with Stanford Research Institute. S.R.I. had developed a model, since converted into a number of algorithms, which calculates reorder points and optimum order quantities. These calculations take into consideration not only usage and lead time, but also anticipated one-time "lumpy" demands and, most important, the degree of criticalness of each item in the inventory in respect to its influence on the overall operation of the Transit Authority. This rating is determined on the basis of simple criteria. If we cannot run the system without the item, it rates No. 1; if we are able to operate without it, but it's still a necessary item, it rates as No. 3. Anything in between rates as No. 2. The criticalness ratings ensure that within the service levels we prescribe, our inventory resources are concentrated on those items most critical to the operation.

One of the features of this new stores system is that it permits the manager to simulate the inventory cost needed to provide certain service levels. Thus, we can say that we want our inventory to have an average service level of no more than one stock-out per line item every three years, and then calculate what the cost of maintaining the needed inventory will be. At the time the first analysis was made, the model indicated that with the then current inventory of "A" items distributed as they were, we could expect to experience one stock-out occasion in each line item every 3.4 years. The model also indicated that if we followed its instructions in restocking the "A" item inventory and if we kept the total inventory value of the same amount, we could improve the service level substantially to one stock-out for each item every 27 years. This illustrates the power of the new system. We decided to shoot for 10 years between stock-outs with a substantial reduction in inventory investment.

The new control system which is being designed and installed to manage the entire inventory is well under way. The new system will provide controls and reports with the following characteristics:

(A) Management reports are generated on a monthly basis providing information for proper operational control and planning.

(B) Unusual conditions and deviations from the norm are high-lighted with follow-up action to correct the conditions when necessary.

(C) The system anticipates when certain time-phased transactions are expected and when such are overdue, the problem areas are highlighted and follow-up action initiated.

(D) Automatic reorder points are designated which reflect current material usage, stock status, procurement action in the works, lead time and criticalness.

(E) Economic order quantities are calculated based on expected lead time, unit cost as well as estimated purchase order processing cost and inventory holding costs.

(F) All steps of the procurement function are monitored to high-light potential lead time problems and to show where expediting action is needed.

(G) The system senses changes in usage rates and issues warning of impending stock-outs which will occur if new usage rates continue. Expediting action can be started to try to prevent the stock-out.

One particular aspect of the system which has been started as part of the SIMS effort is a timeshare computer program which constantly monitors the procurement cycle of the 600 "A" (high usage) items. Each transaction involved in the procurement cycle is monitored, and when the time allowed between any two transactions exceeds the expected time, management attention is called to the condition. The monitoring system compares expected with actual time for:

(1) Preparing the requisition.
(2) Preparing bid documents.
(3) Receiving bids.
(4) Evaluating bids.
(5) Issuing purchase orders.
(6) Expected delivery time.

Whenever a standard time is exceeded, a report is generated. When the actual time already used, added to the standard and expected time for the remaining actions in the cycle exceeds the lead time used to determine the reorder point, the computer notifies management so that action can be taken to try to prevent a stock-out. This aspect of the stores management system can be applied easily by anyone who has a significant procurement work-load.

In summary, the Transit Authority has dealt with its material problem in order of priorities. The most important thing was quickly to eliminate stock-outs. This was done by a massive infusion of money into the inventory. The second step was to improve the management of the inventory so that the required stock availability or service level could be achieved with a minimum investment in inventory. This second half of the problem was approached in what we felt was a systematic way. We analyzed the problem as quickly as its complexity would allow. We formulated a total solution to the problem and made plans to implement that total solution. Then on the basis of our analysis of the problem, we extracted from the overall plan those elements which could be applied quickly without interfering with the overall implementation schedule. We installed those "quick fixes" and, as a result, realized a major portion of the anticipated benefits almost immediately.

The measure of success of the two-stage approach and the efforts exerted by management is that there have been virtually no cars out of service for parts and the Authority has been making virtually 100% of full-scheduled service for two years. On-time performance has been rising steadily from the 1970 low of below 80% to over 97% in recent months. The growth in inventory has turned the corner. From $39.9 million in February 1973, the inventory investment has been cut by $5.6 million to $34.3 million in August 1974.

Material is under control at the New York City Transit Authority.

Report on Assignment 5

Systems Engineering Education—Collect and Disseminate Information to the Association Membership by Means of Special Features, Seminars, Demonstrations and Printed Material

A. D. M. Lewis
Chairman, Subcommittee

Your committee presents as information the following report on computer usage by members of the engineering department of the Southern Pacific Transportation Company.

COMPUTER USAGE IN THE SOUTHERN PACIFIC'S ENGINEERING DEPARTMENT

By R. A. LATHROP[1]

Computer use by members of the Engineering Department of Southern Pacific has evolved around the basic philosophy that each engineer or subdepartment will (1) recognize the problem, (2) analyze and, if possible, program the solution, and (3) maintain and operate the programs as developed.

Our Engineering Department has a minimum staff of engineer programmers to help the individual engineers in development of their programs. The engineer programmers are typically deeply involved in development of research projects and programs, but are available to assist and guide the individual engineer in solving his problems and the development of his programs.

Computer usage in the Engineering Department received its greatest impetus when we purchased a PDS 1020 and installed it in our drafting room in San Francisco, principally to solve the problem of slow turnaround when utilizing the computers maintained by our Systems Research Department, at that time almost entirely dedicated to the accounting function. By putting the PDS 1020 in the close proximity of the engineers, installing it in the middle of the drafting room, we were able to dispel fears of the "black box" and give each engineer a chance to have some hands-on time at a computer. It soon became evident that this small (4K) machine was not sufficient to handle a great portion of our engineering problems, and we supplemented it with time-sharing which we have now been able to establish in our general office in San Francisco, general office in Houston and at three division points.

Time-sharing is used for solutions to the smaller problems and problems which require immediate answers. We are very cost conscious, however, and on programs having a large-core requirement, we are now able to use the Management Information Services machines of our Systems Research Department and have available an IBM 370-158 and usually a 370-168 which is the back-up machine for our TOPS system with overnight turnaround.

---

[1] Assistant Engineer, Southern Pacific Transportation Company.

Some of the programs we have developed for our use include the CARES package of bridge and load analysis which was developed by McDonnell Automation for us. This program analyzes each steel structure by AREA specifications, developing a Cooper load rating for the structure. It also has the ability to analyze a specific load over the structures of a designated route, determining if the load can be safely handled—first, at time-table speed, next if the bridge will support the load at a reduced speed, and finally, walking the load to remove impact. We feel that this is a very beneficial program to us because we are able to rate all our steel structures on a uniform basis according to current AREA specifications. In addition to the load programs, we have added a high-wide section to this so that complete information on loads of any dimension (above those published) clearance can be considered. It should be mentioned that the input for the CARES package has been a large effort in order to permit us to analyze a steel structure. Every member and joint has had to be analyzed and recorded in our data base.

Programs which analyze specific concrete box designs have been developed, and the bridge book, which is a record of each culvert, trestle, and steel bridge on our railroad, is designed to give the Bridge and Building Department a complete record of the present status of the structure. The book is updated by the bridge inspector working in the field, marking the changes right on a computer output, which can then be easily key-punched and the bridge book corrected after each bridge inspection. A separate repair list of work necessary by the field forces is created, also the data base can be interrogated in any number of ways for pertinent information.

Our Bridge Department has used ICES STRUDLE to help analyze structures which are to be built on our property, particularly the type of structure designed by the California State Bridge Department. We have found it advantageous to use the ICES STRUDLE package, particularly for its finite element analysis capabilities.

A program was developed to aid the engineer in planning the redecking of structures, analyzing and providing to the fabricating plant plans for dapping the ties, eliminating many hours of tedious calculations necessary for these specifications. One project which we hope to accomplish in the near future will be the plotting of the bridge ties utilizing our Cal-Comp plotter aiding both the fabricating plant and the field forces in their installation of bridge decks.

Several programs for track geometry have been developed such as design of shooflys, with and without transition spirals, design of spur tracks, vertical curves, etc. Most of our land description work has been handled on the PDS 1020; however, as this machine is an orphan, we have been working with SBC and have had them develop a COGO package which better fits our land description needs and also have encouraged them in the development of a digital terrain model which will be extremely useful where any earth-work problems are encountered, particularly design of line changes where several alternates need to be investigated.

The Electrical Department does not ordinarily use many programs more complex than can be handled on their programmable calculator. However, in one complex problem we had to look at some wave analysis which was greatly facilitated by plotting the information so that it could be readily analyzed. General Electric's outdoor lighting program has also been used, particularly for large areas such as our new Colton yard.

Working with the California Public Utility Commission, we have been able to develop a list of grade crossings from its list, and we expect to be able to obtain some workable files of grade crossing information from the National Inventory.

Our Estimating Department makes good use of cash flow programs and has also developed some lump-sum estimating and estimated ledger value data, which is particularly useful for rail program work. The annual rail program has been automated and furnishes a list of rail renewals, both new and secondhand, with rail and other track material requirements as a by-product for the requisitioning of materials and development of welding schedule at the welding plant.

Budgeting and accounting of the Engineering Department is now handled in a system known as PACE (Planning And Control of Expenditures) which is a responsibility accounting system. All work as performed is reported by three principle codes which describe the supervisor in charge, such as roadmaster, B & B, signal, the authority, whether ordinary operating, GMO, recollectible, etc., and finally the work function. By utilizing these codes, we have greatly reduced the clerical errors which occurred in the field documents which had to be interpreted by new Accounting Department personnel who are unfamiliar with our work terms. The PACE system began, principally, as an Engineering Department function involving the Accounting Department and Systems Research but has now evolved to the responsibility accounting system of the entire Southern Pacific Transportation Company. Among the reports which are obtained are, Production Report, the Rail and Tie Inventory Report, Failed Rail Report, a new report which lists overtime and distributes the overtime to ordinary operating, GMO operating, investment and "other" categories to assist the field personnel in control of overtime in the areas where it is most important to control.

Budget reports on pyramiding levels of control are made comparing actual expenditures to the planned. As all expenditures are recorded in PACE terms, it is possible to obtain DBI's (Data Base Inquiries) as detailed as the problem being studied requires.

Our Valuation Department, which in Southern Pacific is an Engineering Department function, has been very successful in mechanization of many of its tasks. One of the earliest of these was the necessity to re-evaluate the Pacific Electric railroad to steam railroad standards when this property was consolidated with the Southern Pacific Transportation Company. By use of standards, a great deal of field inventory time was saved and the actual valuation records created on the old PDS 1020.

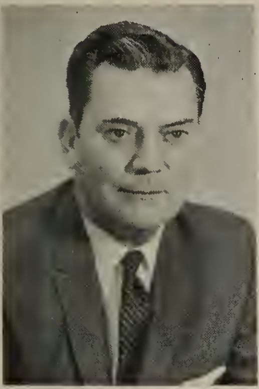
One of the functions of the Valuation Department is the development of the bills on recollectible projects such as grade separations and crossing protection where public bodies participate in the cost. By using the same format as Santa Fe and expanding its re-bill program, we have been able to mechanize this function, saving manpower and also developing bills which are processed much faster by the public bodies who have become familiar with the format of these bills which are easy to read, consistent in content, and easy to follow. This has decreased the float time between billing and payment, also saving a large amount of capital.

We have been very much involved with the track-train dynamics program of the AAR and are using its train performance calculator programs, particularly for the analysis of freight train operations, both where derailments occur and where new operations are being considered. Mr. Lutrell of our department spent some time with the train dynamics group in Chicago helping to develop these programs, and has brought the programs up on our time-sharing, successfully using the program a number of times to help in analysis of derailments.

Plotting using our Cal-Comp drum plotter helps in development of the high-wide data base for the CARES package and is used in development of management graphs for several departments of the railroad.

The contour plotting package has been used in analysis of drainage problems, and cross sections developed from the OTM and other earth-work programs have been effective.

Report of Committee 24—Engineering Education



H. M. Williamson,
Chairman

B. M. Davidson,
Vice Chairman

T. G. Schultz, *Secretary*
W. R. Catching
W. A. Oliver
C. T. Yarbrough

A. L. Sams
R. H. Lee
D. N. Cortright
C. T. Popma
V. J. Roggeveen

T. M. Adams
W. S. Autrey
J. B. Babcock (E)
R. H. Beeder (E)
D. R. Bergmann
J. R. Blacklock
D. M. Brinker
R. M. Brown
C. D. Chambers
J. B. Clark
A. W. Cooper
T. P. Cunningham
R. P. Davis (E)
J. F. Davison
J. T. Evans
E. T. Franzen
L. C. Gilbert
W. W. Hay
W. P. Houwen, Jr.
E. Y. Huang
W. H. Huffman
H. E. Hurst
E. Q. Johnson
F. O. Johnson
A. V. Johnston
C. Johnston
T. D. Kern
C. E. Law
B. B. Lewis (E)
R. G. Michael
J. F. Pearce
S. H. Raskin
D. V. Sartore
P. S. Settle
W. D. Smoak
R. M. Soberman
D. M. Tate
W. D. Taylor
G. H. Way
C. E. Weller
D. L. Wilson

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Recruiting.
   Progress report, presented as information .... page 374

2. Summer Employment.
   Progress report, presented as information .... page 381

3. Student Cooperative Programs.
   No report.

4. Student Affiliates.
   No report.

5. Continuing Education.
   Advance report was published in Bulletin 649, September–October 1974.

6. Speakers.
   No report.

7. Project Case Studies.
   No report.

8. Exchange of Professional Staffs.
   Advance report was published in Bulletin 649, September–October 1974.
9. Research Resource Availability.
   No report.

THE COMMITTEE ON ENGINEERING EDUCATION,
H. M. WILLIAMSON, *Chairman.*

Report on Assignment 1

Recruiting

W. R. CATCHING *(chairman, subcommittee)*, J. B. CLARK, J. T. EVANS, H. E. HURST, CLAUDE JOHNSTON, T. D. KERN, D. V. SARTORE, D. M. TATE.

During 1974, your committee conducted its fourth annual survey of college graduates employed by the railroad industry during the 12 month period August 1973 to July 1974.

Completed survey questionnaires were received from 34 Class I line haul railroads, two Class II railroads and two switching and terminal companies. Briefly, the replies from these 38 companies show a high of 102 graduates employed by one major system, one or more graduates employed by 26 other railroads and no graduates hired during the survey period by the remaining 11 companies.

Table 1 provides a detailed summary of the academic degree, course of study and monthly beginning salaries of 492 graduates employed by 21 railroads during the 12 month period August 1973 to July 1974.

Average beginning salaries reported in these tables again support the findings of our previous surveys that railroad salaries paid new college graduates are generally competitive with salaries paid in other industries. Two deviations, however, may be noted in this year's report when railroad salaries are compared with average salaries in other industries.

Salaries shown for Business and Liberal Arts Bachelors and Associate Degree graduates are somewhat higher than overall industry averages. This is probably due to the frequent assignment of such graduates in recent years to railroad operating positions where salary levels are influenced by the high union scale applicable to subordinate employees covered by labor agreements.

Conversely, average salaries reported for new hires with Graduate Degrees are somewhat lower than those paid in other industries. Individual survey replies from a number of railroads indicate that during the past year a number of advanced degree graduates were hired and placed in railroad positions that are normally filled by Bachelor Degree graduates. This is probably the result of a general softening in the competitive market for graduates with advanced degrees.

Each year our survey questionnaire seeks information on the number of college graduates hired that have had prior railroad experience through summer vacation employment or cooperative education programs. The left section of Table 2 summarizes this data and indicates only 29 of the graduates employed had such a prior railroad relationship. This constitutes just 5.9% of the 492 graduates hired so that prior railroad employment does not appear to have been a meaningful factor this past year in attracting college graduates to permanent railroad careers.

The right section of Table 2 summarizes data from the questionnaire on the prevalence of formal training programs to indoctrinate and prepare newly employed graduates for future supervisory and managerial assignments. Replies from 15 of the 27 employing railroads report that 175 graduates (nearly 36% of the total) were assigned to training programs averaging 11.1 months in duration.

The information presented in Tables 3A and 3B is a continuation of a project added to our survey questionnaire last year. These tables show the number of college graduates by academic degree and course of study assigned to each of 58 different position titles within the various major departments of the reporting railroads.

This glossary of job titles should be of particular interest to the colleges and universities as illustrative of the wide variety of attractive career opportunities available in today's railroad industry.

To conclude the subcommittee report, Table 4 provides a year-by-year trend comparison of the number of college graduates hired and average beginning salaries paid in each of the four years of our survey, August 1970 to July 1974.

In support of the comparability of this trend data, it should be noted that the major portion of our input material has been supplied by the continued year-by-year reports from all of the larger U.S. railroads. Some variations have occurred in the continuity of replies from smaller roads; however, their occasional employment of a few college graduates has had little effect on the annual summaries.

It is apparent from these year-by-year totals that a change in composition by academic degree and course of study has been occurring in college graduates accepting employment in the railroad industry. Engineering Bachelors show a somewhat erratic but general decline; however, this has been more than offset by an increase in the Business and Sciences category and in Associate Degree graduates.

This four-year change in composition can probably be considered a continuation of a much longer range trend in college graduates hired by the nation's railroads.

Historically, most railroads recruited college graduates primarily for operating department positions with emphasis on civil and mechanical engineers. However, in recent years, many graduates with degrees in business, liberal arts and sciences have been hired and placed in various departments other than operating (see Table 3B). In addition, the prolonged short supply of engineers to meet the needs of industry generally has contributed to the increased employment of two-year Associate Degree graduates and non-technical Bachelors for operating assignments (see Table 3A).

TABLE 1. DEGREE, COURSE OF STUDY AND MONTHLY BEGINNING SALARIES
OF COLLEGE GRADUATES EMPLOYED BY 27 RAILROADS
IN THE 12 MONTHS AUGUST 1973 TO JULY 1974

Degree and Course of Study	Number of Employing Railroads	Number of Graduates Employed	Monthly Beginning Salaries Lowest	Highest	Average
ASSOCIATE DEGREE (Two years of study)					
Non-Technical Curriculum	7	18	$ 700	$1,250	$ 861
Technical Curriculum	12	37	695	1,216	857
Sub-Total	13*	55	$ 695	$1,250	$ 859
BACHELOR DEGREE (Business & Sciences)					
Accounting	7	40	$ 756	$1,298	$ 926
Business-General	12	73	775	1,250	885
Humanities & Social Sciences	9	79	700	1,200	885
Marketing & Distribution	7	16	775	1,200	870
Sciences (Chem., Math., Physics)	13	60	720	1,200	871
Sub-Total	15*	268	$ 700	$1,298	$ 888
BACHELOR DEGREE (Engineering)					
Civil Engineering	19	57	$ 800	$1,100	$ 949
Electrical Engineering	9	17	782	1,047	938
Industrial Engineering	8	14	883	1,200	964
Mechanical Engineering	8	14	830	1,000	929
Other Engineering	11	18	860	1,250	964
Sub-Total	23*	120	$ 782	$1,250	$ 949
GRADUATE DEGREE					
MS-Engineering or Science	6	9	$ 900	$1,150	$ 998
MBA-After Non-Technical Degree	6	27	800	1,375	1,007
MBA-After Technical Degree	4	6	885	1,050	918
LLB or JD - Law	4	7	1,000	1,150	1,053
Sub-Total	12*	49	$ 800	$1,375	$1,000
GRAND TOTAL	27*	492	$ 695	$1,375	$ 911

*Count of employing railroads by degree categories will not add to totals.

TABLE 2. PRIOR RAILROAD EXPERIENCE AND INITIAL ASSIGNMENT OF COLLEGE GRADUATES EMPLOYED BY 27 RAILROADS IN THE 12 MONTHS AUGUST 1973 TO JULY 1974

Degree and Course of Study	Number of Graduates Employed: With Prior RR Experience: From Co-Op Programs	Number of Graduates Employed: With Prior RR Experience: Summer Vacation	Number of Graduates Employed: Without Railroad Experience	Number of Graduates Employed: Total Graduates Employed	First Assignment: To Regular Position	First Assignment: To Formal Training Program	First Assignment: Training Period (Months)
ASSOCIATE DEGREE (Two years of study)							
Non-Technical Curriculum	-	2	16	18	17	1	(12.0)
Technical Curriculum	-	-	37	37	31	6	(9.0)
Sub-Total	-	2	53	55	48	7	(9.4)
BACHELOR DEGREE (Business & Sciences)							
Accounting	-	-	40	40	21	19	(16.1)
Business-General	1	2	70	73	41	32	(11.3)
Humanities & Social Sciences	-	2	77	79	55	24	(9.2)
Marketing & Distribution	-	4	12	16	7	9	(10.7)
Sciences (Chem., Math., Physics)	1	-	59	60	44	16	(12.9)
Sub-Total	2	8	258	268	168	100	(11.9)
BACHELOR DEGREE (Engineering)							
Civil Engineering	7	3	47	57	34	23	(10.3)
Electrical Engineering	-	1	14	17	9	8	(12.3)
Industrial Engineering	-	-	14	14	6	8	(9.3)
Mechanical Engineering	-	-	14	14	6	8	(8.8)
Other Engineering	1	-	17	18	15	3	(7.0)
Sub-Total	10	4	106	120	70	50	(10.0)
GRADUATE DEGREE							
MS-Engineering or Science	1	-	8	9	7	2	(12.0)
MBA-After Non-Technical Degree	-	1	26	27	13	14	(10.3)
MBA-After Technical Degree	-	-	6	6	5	1	(9.0)
LLB or JD - Law	-	1	6	7	6	1	(3.0)
Sub-Total	1	2	46	49	31	18	(10.0)
GRAND TOTAL	13	16	463	492	317	175	(11.1)

TABLE 3A. GLOSSARY OF JOB TITLES IN FIRST ASSIGNMENT
OF COLLEGE GRADUATES EMPLOYED BY 27 RAILROADS
IN THE 12 MONTHS AUGUST 1973 TO JULY 1974

JOB TITLE IN FIRST ASSIGNMENT TO POSITION IN OPERATING DEPARTMENT	ASSOCIATE DEGREE		BACHELOR DEGREE (Business & Sciences)					BACHELOR DEGREE (Engineering)					GRADUATE DEGREE				TOTAL
	Non-Technical Curriculum	Technical Curriculum	Accounting	Business-General	Humanities & Social Sciences	Marketing & Distribution	Sciences (Chem., Math., Physics)	Civil Engineering	Electrical Engineering	Industrial Engineering	Mechanical Engineering	Other Engineering	MS-Engineering or Science	MBA-After Non-Technical Degree	MBA-After Technical Degree	LLB or JD - Law	
Architect												1					1
Assistant Engineer								4	2	2	2	1					11
Assistant Mechanical Engineer											2						2
Assistant Roadmaster								5			1						6
Assistant Signalman		3							1								4
Assistant Trainmaster					15						1		2				18
Assistant Water Chemist							2										2
Chainman							2										2
Clearance Engineer		1															1
Civil Engineer								3									3
Communications Engineer													1				1
Designer								1					2				3
Draftsman	10	13		1	3			4	3		1	9			2		46
Engineering Aide		3						5									8
Engineering Assistant	2	2										1					5
Engineer Computer Analyst													1				1
Engineering Trainee								3		1							4
Field Engineer-Electric Traction									1								1
General Foreman										2	4	1					7
Industrial Engineer										2							[illegible]
Inspector-Operations				1	1		1										3
Instrumentman		2						1									3
Junior Engineer								5	5			2	1				13
Junior Designer								4									4
Planning Supervisor				2				1									3
Pollution Control Specialist							1										1
Project Engineer												1	1				2
Rodman	2							3			2						7
Spectrographer							1										1
Staff Engineer								1									1
Track Supervisor								9									9
TOTAL	14	24	-	4	19	-	9	[illegible]	12	7	13	16	[illegible]	-	[illegible]	-	178

TABLE 3B. GLOSSARY OF JOB TITLES IN FIRST ASSIGNMENT
OF COLLEGE GRADUATES EMPLOYED BY 27 RAILROADS
IN THE 12 MONTHS AUGUST 1973 TO JULY 1974

JOB TITLE IN FIRST ASSIGNMENT TO POSITION IN DEPARTMENTS OTHER THAN OPERATING	ASSOCIATE DEGREE		BACHELOR DEGREE (Business & Sciences)					BACHELOR DEGREE (Engineering)					GRADUATE DEGREE				TOTAL
	Non-Technical Curriculum	Technical Curriculum	Accounting	Business-General	Humanities & Social Sciences	Marketing & Distribution	Sciences (Chem., Math., Physics)	Civil Engineering	Electrical Engineering	Industrial Engineering	Mechanical Engineering	Other Engineering	MS-Engineering or Science	MBA-After Non-Technical Degree	MBA-After Technical Degree	LLB or JD - Law	
ACCOUNTING & FINANCE																	
Assistant Economic Analyst							1										1
Collection Representative.	1		1														2
Financial Analyst														2			2
Internal Auditor			[illegible]				1										7
Junior Roadway Accountant		1	1			1											3
Property Tax Analyst				1													1
Traveling Auditor			4	1													[illegible]
COMPUTER SERVICES																	
Assistant Computer Programmer					16		18						1				35
Assistant Project Analyst				12										5			17
Data Communications Supervisor												1					1
Electronic Technician		4															4
Systegrammer					1		2								1		4
Systems Development Trainee		4					1										5
LEGAL & CLAIM																	
Attorney																[illegible]	[illegible]
Assistant Commerce Counsel																1	1
Claim Agent					2												[illegible]
MARKETING & SALES																	
Market Analyst				1	3	1								3	3		11
Marketing Trainee				1		1											2
Rate Analyst					1	1											2
Sales Representative				22		2											24
Sales Trainee					3												3
OTHER FUNCTIONS & GENERAL TITLES																	
Clerk (Various)			[illegible]	11	[illegible]	[illegible]											[illegible]
Cost Analyst			1	1			1							[illegible]			6
Examiner-Labor Relations				1	1									1			3
Management Trainee			17	[illegible]		1	4			1							[illegible]
Real Estate Trainee	1				1												[illegible]
Research Assistant				1		1	1										[illegible]
JOB TITLES NOT REPORTED	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	1	1		13		1	[illegible]
TOTAL	4	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	1	[illegible]	4	7	[illegible]

TABLE 4. FOUR YEAR COMPARISON OF COLLEGE GRADUATES EMPLOYED AND BEGINNING SALARIES PAID BY AMERICAN RAILROADS AUGUST 1970 to JULY 1974

Degree and Course of Study	Number of Graduates Employed				Average Monthly Beginning Salaries			
	Aug. 1970 to July 1971	Aug. 1971 to July 1972	Aug. 1972 to July 1973	Aug. 1973 to July 1974	Aug. 1970 to July 1971	Aug. 1971 to July 1972	Aug. 1972 to July 1973	Aug. 1973 to July 1974
ASSOCIATE DEGREE (Two years of study)								
Non-Technical Curriculum	7	5	15	18	$ 656	$ 658	$ 785	$ 861
Technical Curriculum	14	49	25	37	750	780	802	857
Sub-Total	21	54	40	55	$ 719	$ 769	$ 795	$ 859
BACHELOR DEGREE (Business & Sciences)								
Accounting	17	18	20	40	$ 775	$ 768	$ 881	$ 926
Business-General	53	94	49	73	784	812	903	885
Humanities & Social Sciences	45	50	55	79	769	798	858	885
Marketing & Distribution	37	10	38	16	732	799	830	890
Sciences (Chem., Math., Physics)	31	67	59	60	785	811	842	871
Sub-Total	183	239	221	268	$ 769	$ 805	$ 861	$ 888
BACHELOR DEGREE (Engineering)								
Civil Engineering	89	57	101	57	$ 850	$ 883	$ 899	$ 949
Electrical Engineering	23	16	16	17	873	878	905	938
Industrial Engineering	19	13	7	14	847	879	960	964
Mechanical Engineering	24	22	17	14	863	906	904	929
Other Engineering	12	8	16	18	802	842	900	964
Sub-Total	167	116	157	120	$ 851	$ 883	$ 903	$ 949
GRADUATE DEGREE								
MS-Engineering or Science	9	6	10	9	$ 940	$ 942	$1,035	$ 998
MBA-After Non-Technical Degree	32	37	28	27	942	938	1,036	1,007
MBA-After Technical Degree	13	6	5	6	1,038	929	1,045	918
LLB or JD - Law	7	6	7	7	983	1,028	1,044	1,053
Sub-Total	61	55	50	49	$ 967	$ 947	$1,038	$1,000
GRAND TOTAL	432	464	468	492	$ 826	$ 837	$ 888	$ 911

Report on Assignment 2

Summer Employment

W. A. Oliver *(chairman, subcommittee)*, A. W. Cooper, J. F. Davison, E. T. Franzen, A. V. Johnston, D. V. Sartore, W. D. Taylor, D. L. Wilson.

Since 1959, Committee 24 has canvassed the railroads during late December concerning their possible summer employment needs for the following summer. A brief questionnaire has been sent to the chief engineering and maintenance officers and chief personnel officers of the railroads of the United States and Canada requesting information about their needs of young engineering students for employment during the vacation months of the following year.

The response on the part of the railroads to the questionnaire has been decreasing during the past several years, particularly the favorable response, and the question was raised in Committee 24 on the desirability of continuing the program. It was decided to question the nine favorable participants in the 1974 program regarding their opinion concerning its continuance. Of eight replies to the letter raising the question, four were favorable and four unfavorable or indifferent. The following is a quotation from one of the favorable reply letters.

> "I am sorry to find that the interest in this area has decreased among our fellow railroads. Not only do I believe it should be continued but I feel strongly that we are going to need it much more in the future than we do even now. The engineer crunch has hit us at least one, if not two, years earlier than most of us expected. This has probably been primarily due to the energy crisis and the oil companies' rush to staff for expanded refining activity.
>
> "Regardless of the cause, it seems to be very apparent that we are going to have great difficulty competing for the graduate engineers unless we intensify our efforts in pre-graduation recruiting through summer and cooperative education programs. I, for one, vote very heavily in favor of continuing the questionnaire and dissemination of the results to the various universities and colleges. If we can provide you with any support in this area, do not hesitate to contact us."

As a consequence the committee decided to continue the program for another year.

Following is the regular yearly report on the responses to the questionnaire. The figures for 1973 are included for comparative purposes.

1974 Summer Employment

	Number of Railroads
Offering employment through Committee 24	9
Offering employment but *not* through Committee 24	29 (38)
No employment in 1974	11
Total return of questionnaire	49

1973 SUMMER EMPLOYMENT

	Number of Railroads
Offering employment through Committee 24	8
Offering employment but *not* through Committee 24	22 (30)
	—
No employment in 1973	19
	—
Total return of questionnaire	49

Committee 24 again thanks the railroads for their cooperation.

Report of the Committee on Electrical Energy Utilization

A. B. Costic, *Chairman*

R. U. Cogswell,
Vice Chairman

B. A. Ross,
Special Assistant

L. D. Tufts
H. Rappaport
K. B. Ullman
R. J. Berti
T. B. Bamford
E. C. Anderson, Jr.
D. M. Twine
F. T. Snider

B. Anderhous
J. A. Angold
A. R. Barker
R. F. Breese
W. H. Brodsky
C. A. Bunker
N. P. Cain
R. F. Carter
W. J. Clarke
A. G. Craig, Jr.
L. L. Earley
R. A. Falcon
E. K. Farrelly
H. T. Foy
W. S. Gordon
E. M. Hastings, Jr.
R. L. Henderson
H. C. Kendall
E. W. Koch
K. L. Lawson
A. W. Lewis
K. Loebl
R. W. McKnight
M. D. Meeker, Jr.
H. S. March
C. G. Nelson
K. S. Niemond
A. G. Raabe
R. P. Reiff
M. J. Shearer
E. B. Shew
J. J. Schmidt
R. A. Senffner
W. H. Siemens
J. L. Sinclair
F. W. Waterman

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and special assistant, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Electrification Economics.
   No report.

2. Clearances.
   No report.

3. Voltage Standards.
   No report.

4. Electrification Map.
   No report.

5. Bibliography.
   No report.

6. Catenary State-of-Art.
   No report.

7. Signal and Communication.
   Progress report, presented as information .... page 384

8. Substations.
   No report.

9. Protection and Fault Detection.
   No report.

10. Third Rail and Direct Current.
    No report.

11. Wire and Cable.
    No report.

12. General Applications.
    No report.

13. Electrolysis and Cathodic Protection.
    No report.

THE COMMITTEE ON ELECTRICAL ENERGY UTILIZATION,
A. B. COSTIC, *Chairman.*

Report on Assignment 7

Signal and Communication

E. C. ANDERSON *(chairman, subcommittee)*, H. C. KENDALL, M. J. SHEARER.

1. Abstract

When an operating railroad is electrified, the propulsion power may produce effects on the signaling and communication facilities which require conversion for compatibility. This paper explains the role of signaling and communications in railroading, the effects of electrification and the requirements for conversion of facilities.

2. The Role of Signaling

Railroad signaling was first installed for providing safe train movement. Even though safety is still a prime requisite for signal systems, for many years the decisive factor has been the economic justification—increasing the traffic capacity of a line, increasing utilization of the physical plant, expediting train movements, and other benefits. Signals, on the wayside or in the locomotive cab, inform the engineman when he may move his train, and at what speed.

The railroads are the safest form of transportation today. This has been achieved through the establishment of maintenance standards and practices for railroad signaling by the Association of American Railroads and the Federal Railroad Administration. In fact, the basic principle for these standards and practices—"fail-safe"—has become a popular catchword.

The railroad is the only means of transportation which continuously checks the integrity of its path—through track circuits which detect the presence of trains, breaks in the rails, or misalignment of switches—and through devices which detect slides, high water, and other unsafe track conditions. Other devices detect unsafe equipment, such as dragging equipment, overheated bearings, and oversize or shifted loads.

Signal standards and practices also demand a very high level of reliability, both to promote safety and to facilitate train movement. Since much railroad territory is remote, a failure of signal equipment, particularly during a maintainer's off-duty hours, can delay several trains. This can cost hundreds of dollars in extra wages, fuel, freight car per diem charges and other penalties.

Obviously, the higher standards for railroad signal hardware and systems required for safety, greater reliability and more adverse exposure, increase their costs by comparison with supposedly similar commercial hardware.

The higher standards have not hindered progress. On the contrary, the railroad signal industry has led in the development and application of hardware and systems now in widespread industrial usage, including such items as transformers, AC power transmission, batteries, rectifiers, relays, vacuum tubes, coded control systems, remote vehicular control, and traffic control systems.

3. The Role of Communications

Nearly everyone makes use of the common forms of communications—television, radio, telephone, mail, loud-speakers, voice, hand signals, punched cards and hard copy. Many talk freely about microwave satellites, voice and data transmission, computers and peripheral gear.

The railroads make use of practically every form of communications, and have led in the development and application of many.

To understand the railroad need for communications let us consider some facts about freight traffic, which accounts for 90% of total operating revenue. About 2 million freight cars can be moved over most of the railroad track in the United States, Canada and Mexico—approximately 250,000 miles of road and 400,000 miles of track. It takes about 27,000 locomotive units to handle this traffic, both in trains and switching. The ten largest railroads own about half of this equipment and track.

Approximately 11% of these freight cars and 25% of the locomotive units are in freight trains, moving about 500 miles in a day. About 5% of the cars are in customers' sidings or loading and unloading areas. The remainder are mostly in terminals being serviced or repaired, being classified and assembled into trains, or standing idle during seasonal lulls in car demand. This equipment occupies about 5% of the total railroad track.

Just to keep track of the location of these freight cars on a single large railroad—in trains, in terminals, in customers' sidings, or other spots—takes an enormous amount of communications. Add to this the need for billing information, interchange information, controlling the proper distribution of cars and locomotives to handle traffic, passenger traffic and all the other usual business communications.

4. Centralized Traffic Control

While signaling and communications have acquired vital roles in railroad operations independently, their cooperation in Centralized Traffic Control (CTC) has been synergistic.

In CTC, the movement of trains is directed by signals controlled from a central point, without use of train orders or rules concerning superiority of trains. In practice, CTC consists of a combination of automatic block signal systems and interlockings, controlled from a central console through a communication system.

Displayed on the central console track diagram are indications showing the location of trains, the position of track switches, and the aspects displayed by interlocking signals. A train graph records movements of trains through key locations. The dispatcher directs the movement of trains by controlling the interlocking signals at ends of siding or at crossover switches, and by remotely controlling switch positions, thereby aligning the desired route. In CTC territory, the train crew is authorized to move its train in accordance with signal aspects.

Safety resides in the signaling system. The dispatcher cannot set up conflicting train movements or other unsafe conditions. However, the dispatcher has a continuous overall picture of the entire stretch of railroad under his direction. He knows the consist of all trains and the way they are behaving. Consequently, he can change the routing or delay some trains to expedite others. Frequently, he can direct movements so that trains pass at sidings without stopping. Frequently, radio is used for voice communication between the dispatcher and the train crew to improve operation. Telephones are usually installed at strategic locations for emergencies.

CTC can produce some startling results. On one 90-mile stretch through mountainous territory, the average number of trains, standing or moving at any time, dropped from eight to three as soon as CTC became operative, while their traveling time dropped by 60%. Where did the trains go? They were hauling freight on some other line. In a time of expanding traffic, the savings of those five trains paid for the CTC installation many times, including the cost of related track changes such as the lengthening of some sidings and the elimination of others.

CTC frequently can make one track do the work of two, or two tracks the work of three or four, thus reducing the railroad investment while improving train operation. That is why nearly half of the track now signaled in the United States is controlled by CTC.

	Road	*Track*
Total mileage	204,000	333,000
Signaled	100,000	121,000
CTC	40,000	48,000

There are also beneficial side effects. Roadway maintenance and emergency repairs are more efficiently handled. CTC tends to smooth out traffic, reducing peak loads in adjacent territories.

The need for still better control of train movements has increased by recent changes in the Federal Railroad Administration regulations concerning the maximum hours of continuous duty for train crews. The maximum time has been reduced to 12 hours. The rules for time between work periods have also been changed. Minimizing train delays is even more important.

Traffic growth or changes in traffic or equipment may suggest the need for extending or modifying CTC, including elimination, extension or relocation of sidings.

5. Electrification Effects

Now let us consider why electrification affects signaling and communication systems. Basically, power systems, including propulsion systems, generate, transmit, and distribute relatively large amounts of electrical energy. Communication systems, including signaling systems, use relatively small amounts of electrical energy for the transmission of signals.

Power circuits will produce extraneous voltages and currents in communications circuits. Unless the power and communications systems are properly coordinated, this interference can result in hazards to persons, damage to equipment and interruptions in service.

Coordinating the location, design, construction, operation and maintenance of power and communication systems and facilities is required to prevent interference. This involves not only the coordination of power systems with communications and signaling systems, but also the mutual interrelationships between each and every circuit in the vicinity. Nor can we forget the effect of railroad systems on other utilities and the public.

Railroad signal systems are exposed to 60 Hz interference in three principal ways:

(1) From the effects of earth voltage gradients which can cause foreign current to flow in track circuits due to conductive coupling between the track circuit and ground.

(2) From the effects of electrostatic and electromagnetic induction due to the inevitable inductive coupling which exists between the power lines, track circuits, and open-wire signal and communications circuits.

(3) From accidental contact between phase wires of the power line and some part of the signal system.

For safe and reliable railroad operation in signaled territory, it is obvious that no disturbance must occur to the signal system during normal operation of a neighboring power line. Furthermore, during power line fault conditions, the disturbance to the signal system must be so small that unsafe conditions cannot possibly develop. This latter requirement imposes severe criteria on the design of signal and communications systems and the character of the apparatus which may be employed.

Track circuit is basic. Since its invention by Dr. William Robinson over 100 years ago, the track circuit has been the foundation of railroad block signal systems. The track circuit is the medium by which a train or any part thereof may retain continuous and direct control of a block signal while occupying any portion of the track protected by the signal. The completely dependable operation of track circuits under all conditions posed by the environment is a matter of fundamental importance to the railroads in their safe and expeditious movement of goods and people.

Train movements over approximately 121,000 miles of main-line track in the United States today are under block signal control. Five principal types of track circuits are employed by the railroads to meet specific needs: (1) Neutral DC; (2) Coded DC; (3) Continuous AC; (4) Coded AC; and (5) Audio Frequency.

Neutral and coded DC track circuits are employed in non-electrified territory where DC earth voltage gradients are too small to create interference. Continuous and coded AC track circuits are used in either AC or DC electrified territory. In the case of AC electrification, the track circuit must operate at a frequency which is carefully chosen so as to not to conflict with frequencies present in the traction current or the 60 Hz commercial supply. Audio frequency track circuits may be employed in either territory provided suitable precautions are taken in the selection of operating frequencies so as not to conflict with the higher harmonics of the traction current or the 60 Hz commercial supply. In cases where the source of foreign current cannot be completely foreseen (e.g. alternator-type diesel locomotives or variable frequency chopper controlled locomotives), additional precautions must be taken to safeguard against false clears. These means usually include some form of low frequency modulation of the carrier frequency.

The basic safety of a track circuit can be compromised when current from foreign sources flows through the track relay. It might be said that track circuits are victims of their environment. The rails of a track circuit are firmly in contact with the ballast, which is a heterogeneous mixture of stone, dirt, cinder, salt and other chemicals. The conductivity of the ballast and therefore the degree of coupling which exists between a track circuit and ground is a function of moisture and temperature. Leakage paths between rails via the ballast produce a similar effect on track relay current as a train shunt.

Extraneous voltages and currents in circuits may be caused by:

(1) *Magnetic Induction,* an effect produced by the varying current flowing in another conductor.

(2) *Electric Induction,* an effect produced by the voltage impressed on another conductor.

(3) *Ground Potential Conduction,* an effect produced by common use of the ground as a conductor.

(4) *Metallic Cross Conduction,* an effect produced by an accidental connection to another conductor.

6. Magnetic Induction

When current flows in a conductor, a magnetic field is produced around the conductor. The strength of the magnetic field is directly proportional to the current, but decreases with separation in a rather complex way. When the current changes, the strength of the magnetic field also changes, which induces a voltage in any conductors linked by the field. This voltage is proportional to the change in the strength of the field per unit time.

Thus, when an alternating current flows in a conductor, an alternating voltage of the same frequency is induced longitudinally along a parallel conductor. This induced voltage is proportional to the current, the frequency, and the length of exposure, but decreases with the separation between conductors. One-thousand amperes at 60 Hz can produce 700 volts per mile in a parallel conductor separated by about 12 ft, or 550 volts at about 43 ft, with a distant return path.

However, current flowing in the return path may reduce the induced voltage. The current in a return metallic conductor is in phase with the current in the first conductor, but opposite in direction of flow, so that the two induced voltages indicated by dashes and dotted circles, are opposite in phase.

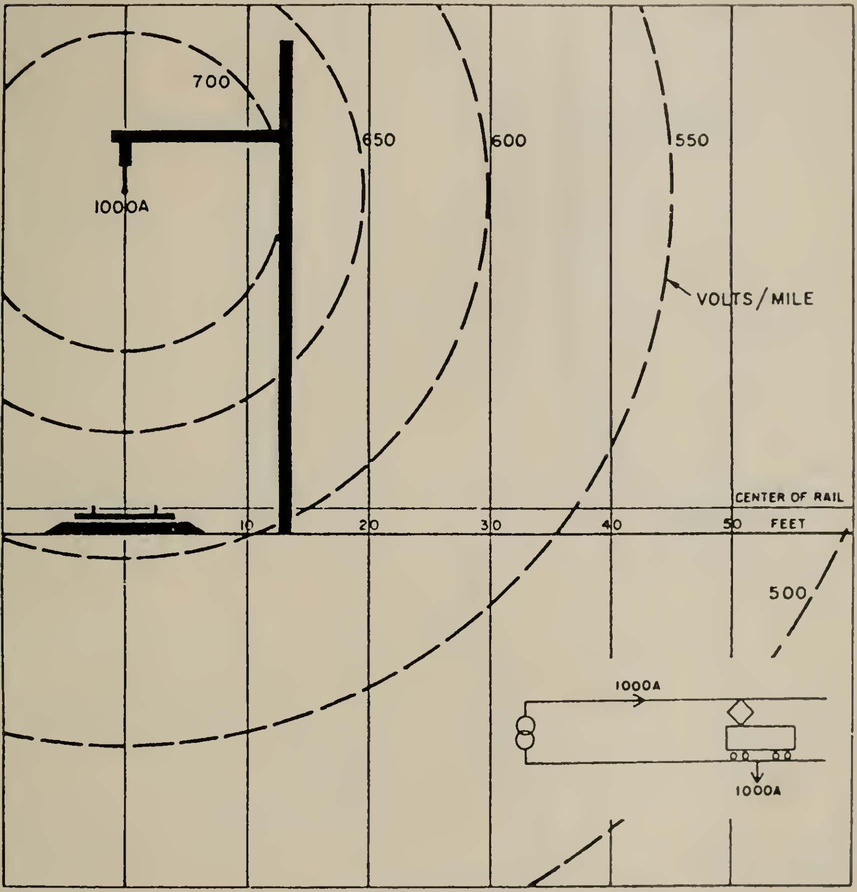
These induced voltages cancel on the midway neutral plane, and reduce the net induced voltage on parallel conductors at other points.

Thus, if a propulsion system carries 1000 amperes at 60 Hz, all of which returns in the rails, the net induced voltage is reduced to a small percentage of that due to the catenary current alone.

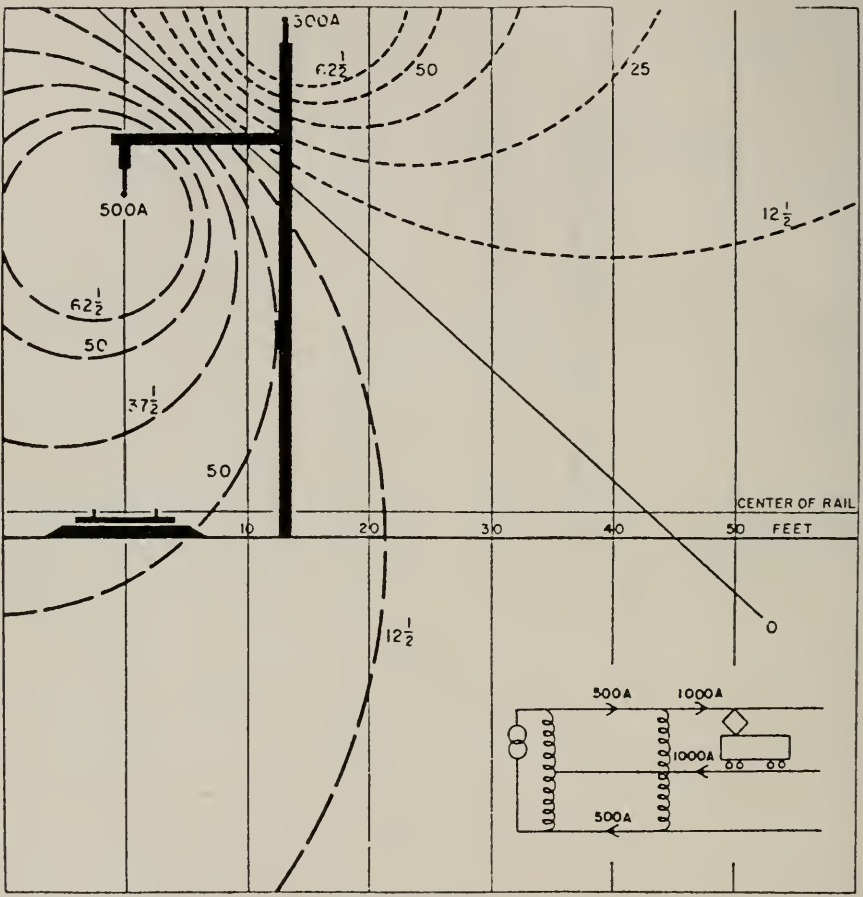
Unfortunately, the rails are substantially grounded through the ballast, so part of the return current usually flows through the ground. The phase angle of the ground return current differs from that in the rails, and even differs in the various ground paths, which reduces the shielding effect. Furthermore, the effective return path is at much greater distance from communication wires than the rails. The depth of the ground return current depends primarily upon the earth resistivity and the distance between a train and the feed point.

To simplify the complex relations, if we assume that the return current flows at a ground depth of 250 ft below the catenary contact wire, the voltage induced on parallel communication lines could be in the order of 200 volts per mile per thousand amperes. This represents a condition where about half the return current flows in the rails, and the remainder through the ground, a fairly typical situation without return feeders.

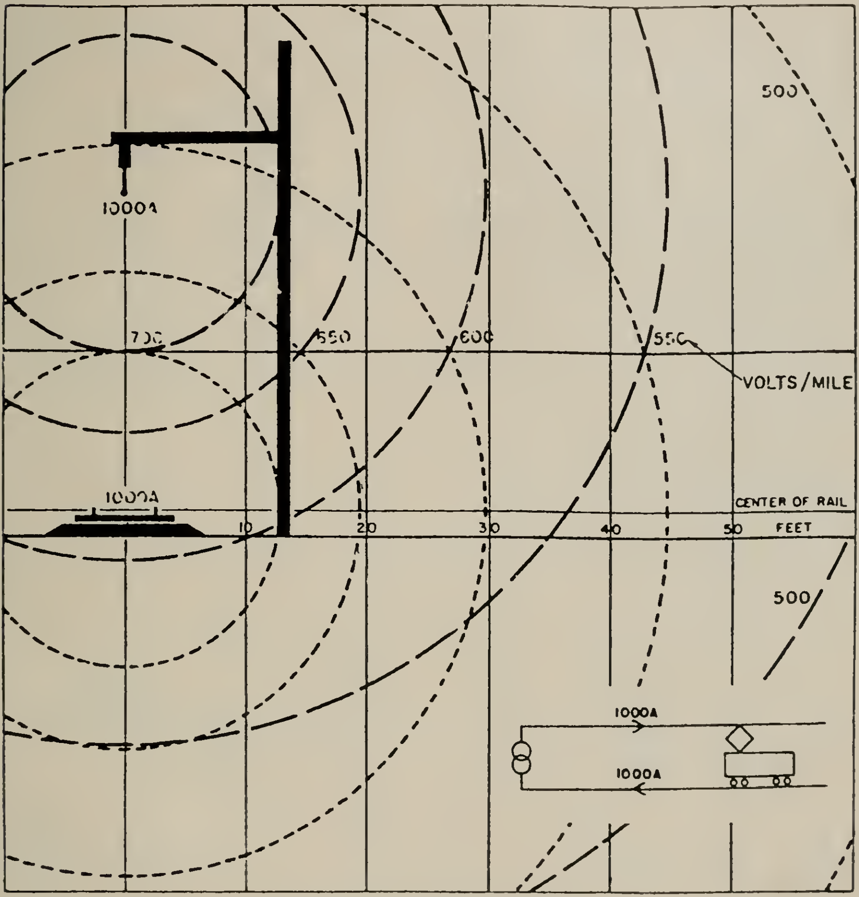
(Text continued on page 396)



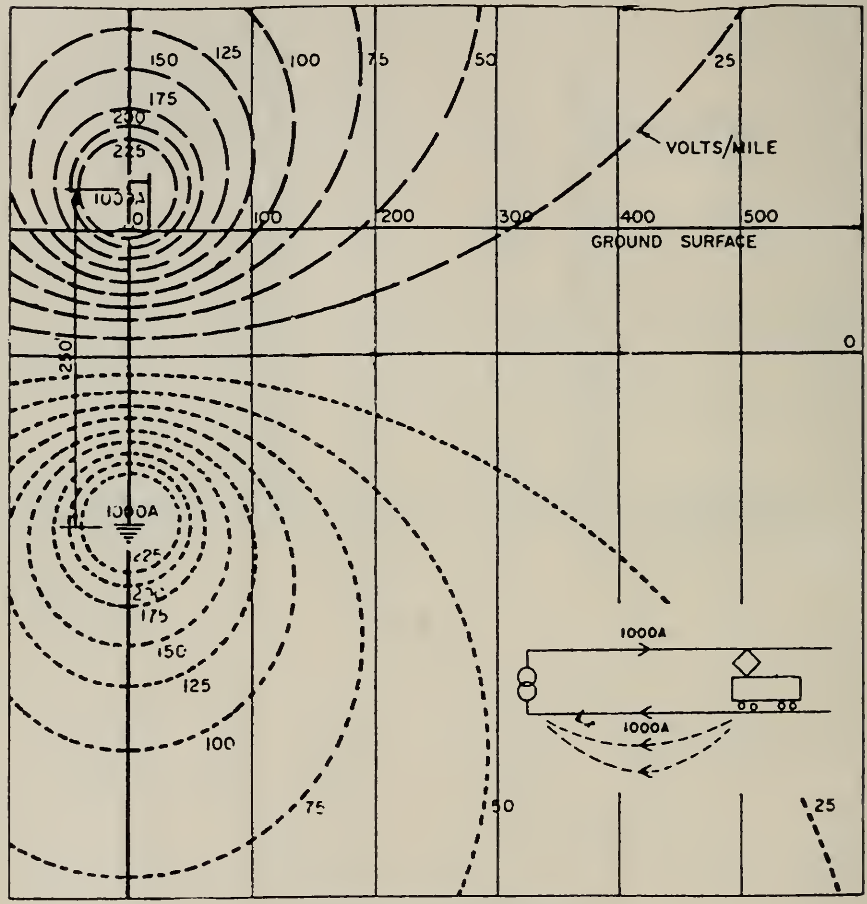
Induction from catenary.



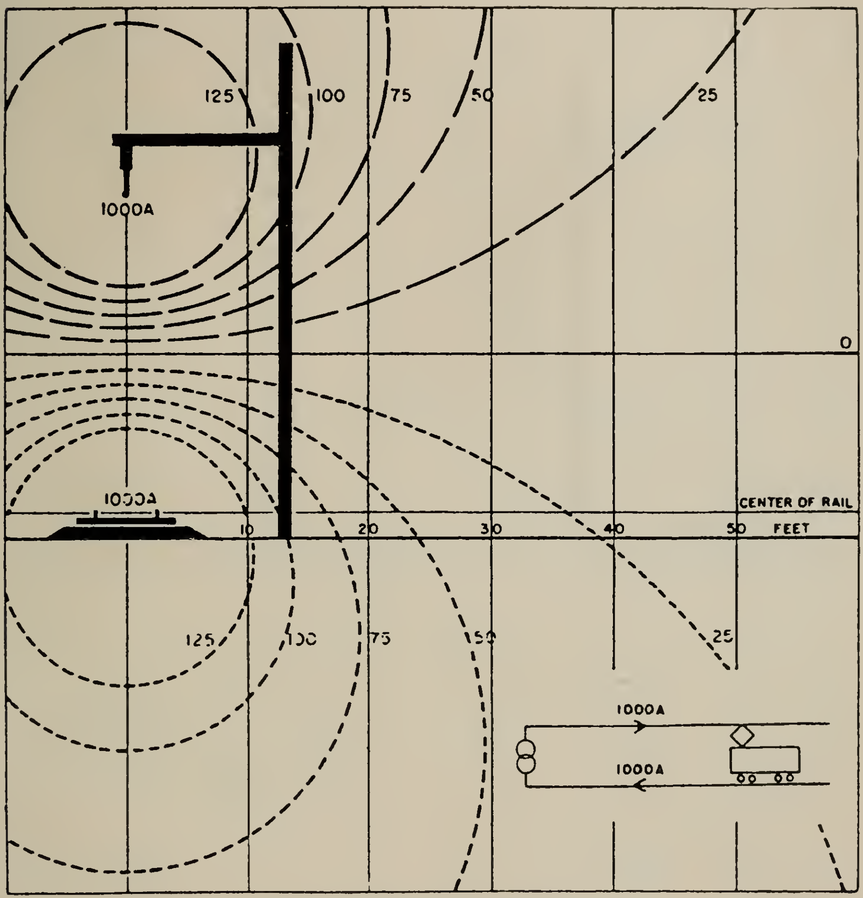
Three-wire induction.



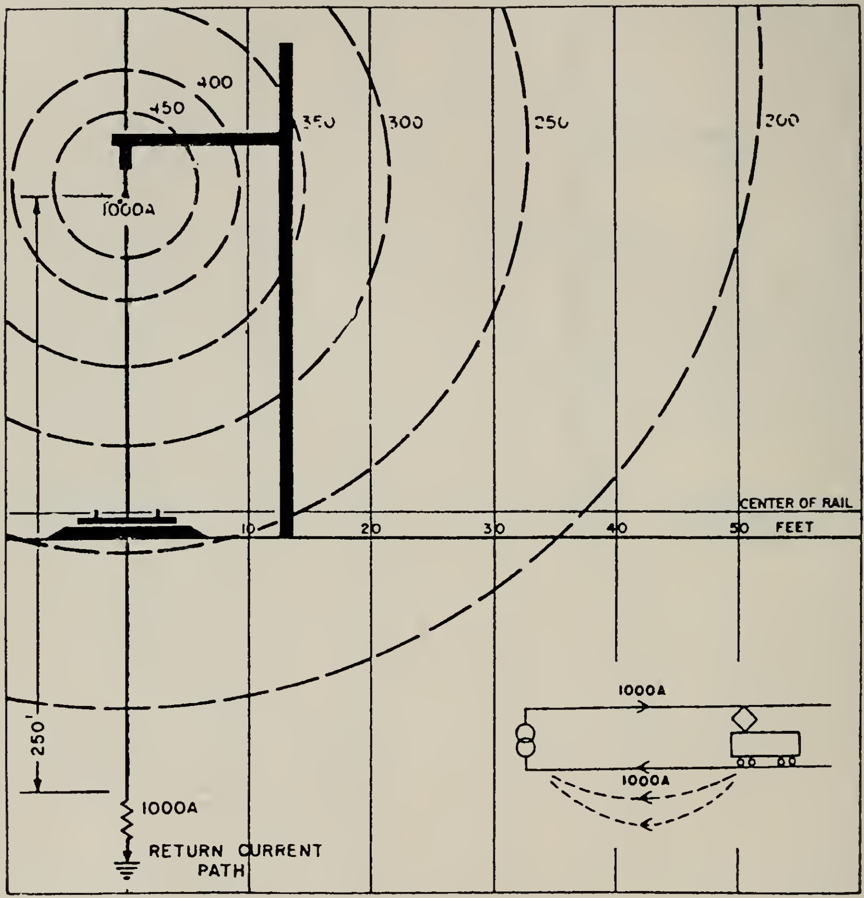
Rail return opposed induction.



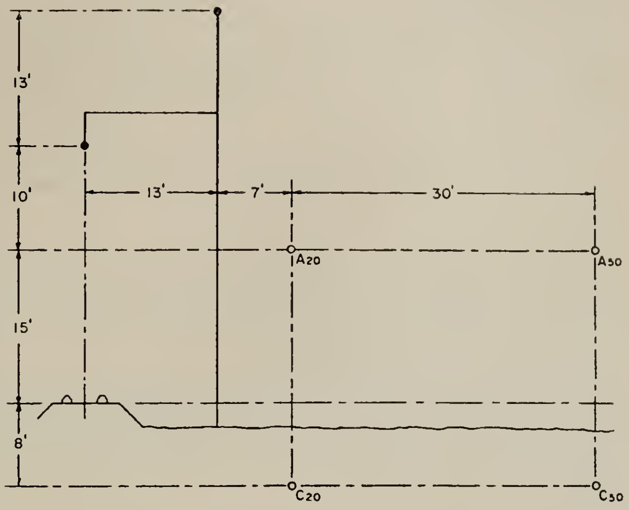
Ground return opposed induction.



Net induction with rail return.



Net induction with ground return.



VOLTS PER MILE PER 1,000 AMPS LOAD 60 Hz.

Return	A20	A50	C20	C50
Deep Ground	629	528	566	508
Typical Ground	284	186	207	156
Rails	13	3	-70	-20
3-Wire System	4	-10	11	-2

One means of reducing the induced voltage over long distances is the three-wire system using autotransformers and a negative feeder. This arrangement minimizes the induced voltage in the unoccupied sections between the substation and the autotransformer, where the return current flows through the negative feeder, and the rail ground currents are negligible. With a two-to-one ratio autotransformer, the catenary and negative feeder current is only half of the load current, and the negative feeder effectively shields communication wires near the neutral planes. This three-wire system also reduces the propulsion voltage drop, and permits longer distances between sub-stations.

The induced voltages shown in this analysis are based on a catenary current of 1000 amperes 60 Hz for convenience. Normal loads would be less, but fault currents could be several times this value. What are the consequences of the induced voltage?

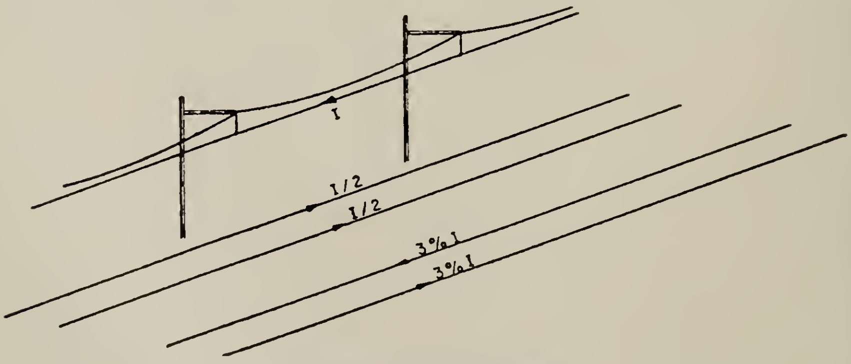
Unless precentive steps are taken, the induced voltage along a wire paralleling a track, for say 10 miles, can reach several kilovolts. This can not only break down insulation or damage equipment, but can also cause a serious hazard to persons contacting such wires or equipment.

Placing the signaling and communication wires in shielded cable wrapped with steel tape and with the shield grounded, can reduce the induced voltage by as much as 95%. But this does not eliminate the hazard to persons contacting such wires or equipment not under railroad control. Even the farmer's fence can be a hazardous liability.

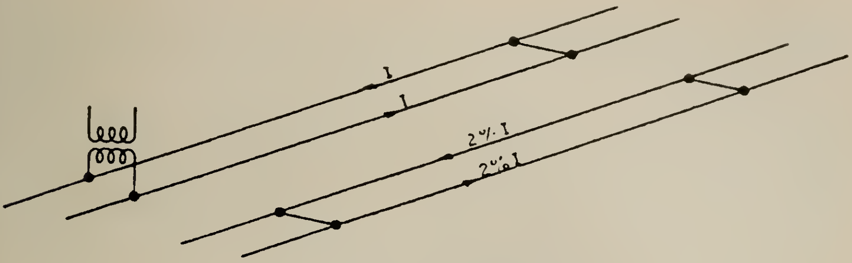
7. Voltage Magnetically Induced in Parallel Wires

In order to keep the induced longitudinal voltage on parallel wires within the recommended limit of 60 volts, it appears to be necessary to minimize the magnetic induction interference at the source, by controlling the return path—by using a three-wire system, booster transformers, or negative feeders. Further improvement can be provided by heavy rail and bonding, cross-bonding, clean ballast, short feeding distances, and locomotive power factor corrections. The signaling and communication cables should be buried as far as practical from the track.

While the largest magnetically induced voltages in the signaling and communication circuits usually arise from propulsion currents, the complete coordination must include the study of magnetic induction between all of the circuits involved.



Induction in adjacent track.



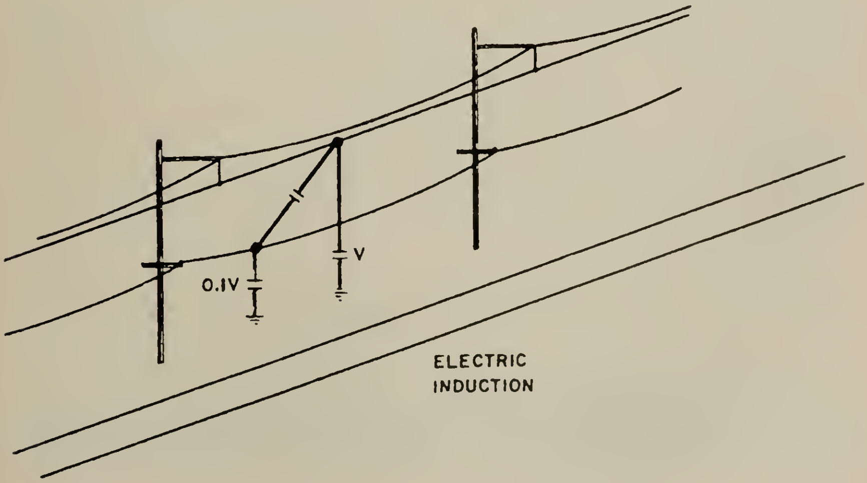
Parallel track induction.

Nearby power lines, normally three-phase, under fault conditions can produce 60 Hz single phase induced voltages of the same order as produced by the propulsion system.

Track circuit design must take into account the effect of magnetic induction, particularly on parallel track. Propulsion current flowing in the catenary and rails of one track will cause considerable unbalance 60 Hz current to flow in an adjacent track. Signaling current flowing in one track induces a current at the signaling frequency in an adjacent track. These factors may limit the safe operable track circuit length, and show the desirability of using rugged equipment, such as impedance bonds, for coupling the equipment to the rails, particularly to guard against fault conditions such as broken rails or short circuits.

8. Electric Induction

Electric induction is an effect produced by the voltage impressed on a conductor through the capacitance between conductors and the capacitance between each conductor and ground. A wire on the catenary pole will have an electrically induced voltage to ground of about 10% of the catenary voltage.



This is another reason for placing signaling and communication wires in cables with grounded shields, which practically eliminates this effect. Burying the cables also eliminates the hunter pot-shot problem, and the steel tape stops pocket gophers.

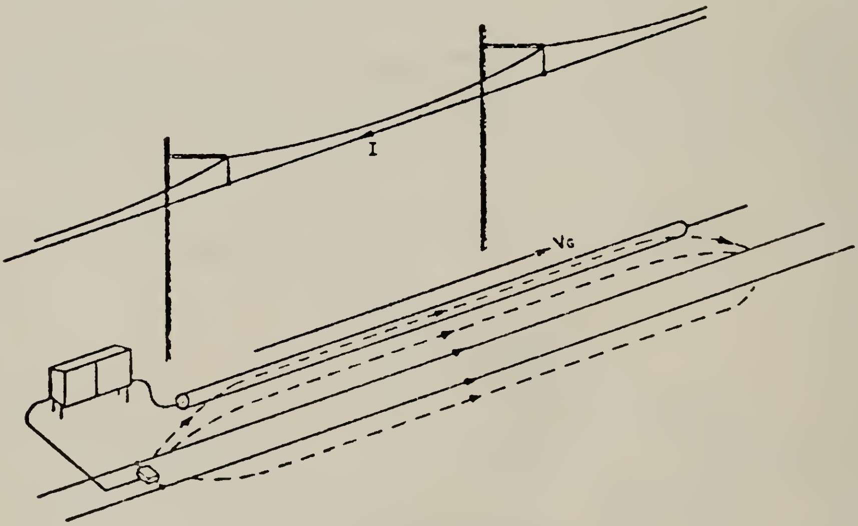
But what do we do about the signal and communications power line? The electrically induced voltage plus the magnetically induced voltage have to be added to the line voltage in determining the insulation requirements for transformers and insulator. This is one reason that signal power line voltage is usually in the same range as that of the propulsion system. As an alternative, signal and communication power can be taken from the propulsion system at each location. The power requirements are low enough that adequate regulation can be provided locally without affecting the propulsion system.

9. Ground Potential Conduction

Ground potential conduction is produced in circuits in contact with the ground, arising principally from the potential drop due to the rail and ground propulsion current. It primarily affects track circuits and grounded case shields.

Track circuit coupling equipment must be rugged enough to withstand the currents which may flow through it. In fact, it is desirable to use impedance bonds even in jointless track circuits, to balance the rail currents and to ground instrument housing to minimize hazard to personnel due to differences in ground voltage. Cable shields must be adequate in conductivity to carry the currents resulting from differences in ground potential. Other circuits must be protected to prevent damage to equipment or hazard to personnel.

We must also consider the ground potential conduction arising from high voltage DC transmission lines.



Ground potential conduction.

10. Metallic Cross Conduction

Metallic cross conduction is produced by a fault, such as a catenary wire falling on a rail. Equipment must be rugged enough to withstand the current surge until breakers operate. Protective devices need to be installed to protect personnel.

11. Facility Conversion

The extraneous voltages and currents arising from induction and conduction are the effects of electrification which will likely force a change in the signaling and communication facilities. These changes include:

(1) Eliminating all wire circuits or placing them in buried, ferrous-wrapped, grounded metallic sheathed cable, limiting cable length between repeaters, with twisted pairs or coaxial conductors, as far from the track as feasible.

(2) Converting track circuits to compatible types.

(3) Properly grounding instrument housings and equipment.

(4) Drawing power from high-voltage lines or from the propulsion system.

(5) Providing protective devices.

Construction under traffic greatly increases construction costs, which can be even higher than the equipment costs, particularly in parts of the country where weather is inclement for long periods, and in remote areas.

Every effort should be made to minimize field construction costs, such as by factory-wired equipment housing, either to replace existing housing, or to aid retrofit equipment while minimizing field wiring.

Another field cost is the moving of signals and the addition of brackets to locate the signal heads where they can be seen, unobstructed by the catenary poles. Consideration should be given to the replacement of wayside signals by cab signals, which may reduce installation costs considerably, and pave the way for Automatic Train Operation. A completely new system may cost less than a retrofit.

In some installations, it may not be feasible to dispense completely with signal and communications wires along the railroad right-of-way. A study needs to be made for each installation to determine the most economical way to handle buried or aerial cable, possible location of such facilities and availability of space, construction and trenching costs, and possible leasing. Radio channels may not be available as an alternative.

Track circuits should be high-level coded AC double-rail track circuits suitable for cab signaling and CTC, expandable for automatic train operation.

The power level must be high enough to provide satisfactory operation through interference. The track circuits should be coded (or modulated) at compatible rates for maximum security. Frequencies must be selected to preclude adverse effects by any interference. This applies to track circuits for both signaling and other purposes such as highway crossing control.

Double-rail track circuits reduce interference, improve broken rail detection, and are required for safe operation of continuous cab signaling. They can be justified economically over single-rail track circuits through longer track circuit lengths and lower propulsion losses.

Track circuits can be installed without insulated rail joints, but this will generally increase the installation cost because more circuits are required, since a number of frequencies have to be used to separate functions and since operable length varies inversely with frequency.

For many railroads, the lowest cost approach would be to convert to 100 Hz coded phase selective track circuits, a recent system proven in service on three American and several foreign railroads; it is directly applicable to cab signal and automatic train operation, with or without cab signals. This system can be used for budget estimates, since it is very doubtful that any other system will appreciably reduce the total cost of electrification.

Signal and communications engineers are frequently asked to give a cost per mile for a compatible track circuit or for signal and communications conversion. This is no more meaningful than asking the cost per mile of highways. It is necessary to consider the entire territory being studied for electrification, and existing facilities.

In the first place, the number of miles may differ or have no relationship to cost. The road mileage is the distance along the railroad line between the ends of the territory, but sometimes there are two routes with different lengths. Communications conductors generally follow the line, but can take shortcuts, or may have additional runs to offline locations, so have about the same mileage, but may vary in number. Track mileage covers all tracks in the territory, including sidings and yards. Catenary mileage is more than road mileage, but less than track mileage. Signaled mileage will not usually coincide with catenary mileage, and really is not the controlling factor in signaling cost.

Signaling cost is more related to its density, which is related to the traffic density. Communications cost will also increase with density. Consequently, the conversion costs will usually be higher where electrification is most likely to be attractive.

In the railroad territory most likely to be considered for electrification, existing track circuits are probably battery-operated and may be coded. Open line wires on a pole line are probably used for some signal circuits, the CTC transmission line, local communications, and a low voltage signal power line.

Construction cost will differ with the railroad and territory. One railroad reported that burying cable with a plow cost only 25 cents per foot; double that figure when a back-hoe was required. Costs pyramided when rocky terrain prevented use of plows or back-hoes. Similarly, problems may be involved in installing equipment housings. Cable costs will vary with the price of copper and the character of the cable.

In several studies, it has been reported that the cable and signal power line accounts for about half of the total signal and communications conversion. The remainder was divided about equally between the wayside signal system, other control and signal systems, and ground material. In each case, construction or assembly accounted for half the cost.

12. Changes to Physical Plant

Most of today's existing railroad plants were designed ages ago, during the steam age when short freight trains less than 3,000 ft in length contended with higher speed passenger trains. For convenience, sidings were generally located near towns where local work was performed and passenger trains made stops. During that age, labor was relatively cheap and equipment was relatively expensive.

Since the advent of the Diesel Age, many changes have come about. Passenger trains have all but disappeared, freight trains have become longer and longer and the relative costs of labor and equipment have reversed. During this time, changes to the physical plant, have, by and large, been nothing but patch-work. This patchwork has imposed ever-increasing burdens on the operations of the railroads. Present day limitations cause many meets that require doubling over to auxiliary tracks. In order to avoid this problem as much as possible, train lengths are often restricted in one direction. This creates an imbalance of motive power and crews. Also, there is a tendency for trains to bunch, which is highly undesirable for operation under electrification—the next age in railroading.

In order to achieve a maximum return on investment with electrification a new approach must be made. Electrification will not submit to ancient design of physical plants, without an enormous increase in cost and operating inefficiency. And in today's high-cost capital market, electrification for electrification's sake would only be foolhardy. If the railroads want to get maximum return on investment, which in fact, they must do, then serious study should be made of the physical plant before miles of catenary are installed. Installing catenary is a difficult and expensive task. On this account, railroads can ill afford to make mistakes. The entire physical plant has to be revamped which makes this the logical time to modernize for present day and future operations. Any patch-work occasioned after original installation incurs major redesign and prohibitive costs.

In short, to take the quantum jump from yesterday's railroading to tomorrow's railroading, no time will be a better time than with the change to electrification.

13. Conclusion

This paper has described the roles of signaling and communications in railroad operations, and their synergistic use in Centralized Traffic Control. It is probable that the signal and communications facilities are adequate for present operations on any railroad with sufficient traffic to consider electrification. The effects of electrification on these facilities, mostly inductive, generally require conversion of these facilities. This conversion must be made without disrupting traffic, which always increases costs.

BIBLIOGRAPHY OF PUBLICATIONS ON RAILWAY ELECTRIFICATION SIGNALING, COMMUNICATIONS AND ELECTRICAL INTERFERENCE

Primary References

1. 95 Hz Phase Selective Track Circuit System as applied to the New York, New Haven & Hartford Railroad. WABCO Publication, 55 pp.
2. Rectifier Motive Power—Inductive Coordination Considerations. K. H. Gordon, et al. AIEE Trans. Vol. 73, pp. 107–118, Paper No. 54–110.
3. Harmonics from Railroad Rectifiers on Power System Reduced by Filters. S. J. Bozzella, et al. AIEE Trans. Vol. 74, pp. 324–335. Paper No. 55–627.
4. Multiple Unit Rectifier Motive Power—Inductive Coordination Considerations on the New York, New Haven and Hartford Railroad. L. J. Hibbard, et al. AIEE Trans. Vol. 76, pp. 416–426, Paper No. 57–207.
5. Electrification—Its Effects on Signaling and Communications. C. E. Staples, IEEE CP71-272-IGA, April 1971, 8 pp.
6. Modernization of Trackside Communications. G. T. Fisher. AAR C&S Section 1971 Annual Meeting, Oct. 1971, 25 pp.
7. Jointless Track Circuits and their application to Electrified Railways. B. H. Grose. Rail Engineering International, June 1973, 7 pp.
8. Report on East Erie Commercial Railroad Inductive Interference Measurements. V. W. Pehrson, General Cable Corporation, August 1973, 37 pp.
9. Wave Propagation in Overhead Wires with Ground Return, by J. R. Carson, Bell System Technical Journal, Vol. 5, 1926, pp. 539–554.

10. Directives Concerning the Protection of Telecommunication Lines Against Harmful Effects from Electricity Lines. (The International Telecommunication Union, Geneva 1963).
11. *Engineering Reports of the EEI*—Bell System Joint Subcommittee, Vol. I to V and also Report No. 50 (1930 to 1943).
12. *Electrical Transmission and Distribution Reference Book,* Chapter 23, Coordination of Power and Communication Systems (Westinghouse Electric Co.).
13. *Interference Between Power Systems and Telecommunication Lines,* by J. R. J. Klewe (Edward Arnold Publishers, London, England, 1958).
14. *Neutral Grounding in High-Voltage Transmission,* Chapter 2, Section 14 by R. Willheim and M. Waters (Elsevier Publishing Co.).
15. Inductive Coordination of Electric Power and Communication Circuits. (J. H. Neblett Pressroom Ltd. San Francisco, 1936).
16. *Association of American Railroads (AAR) Communications Section Manual,* Section 7—Inductive Interference.
17. *REA Telephone Engineering and Construction Manual, Section 451*—Telephone Noise Measurement and Mitigation.

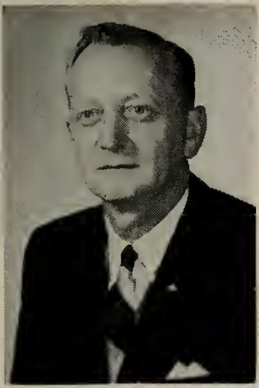
Secondary References

1. Basic Physical Factors Governing Electro-Magnetic Interference Characteristics of a Simple Transmission Line, W. W. Byrne, Frequency Technology, June 1970, p. 9.
2. *Characteristics of Power System Faults to Ground;* Edison Electric Institute, Pub. No. E-9.
3. Circuit Analysis of A-C Power Systems; E. Clarke, 1943, pp. 371–401.
4. Control Circuit Transients, W. C. Kotheimer, Power Systems Management Department, General Electric Company, Power Engineering, January 1969, pp. 22–45 and February 1969, pp. 54–56.
5. Determination of Maximum Potential Rise of Station Ground Grids, by Nicholas Stadtfold, Jr., P. E. Paper presented to the Protective Relaying Committee of the Electric Council of New England. Newport, Rhode Island, April 26, 1968.
6. The Effect of Electric Traction on Signaling and Communication Circuits in Particular Reference to the Means of Overcoming Interference to Provide Safety & Good Communications, *Bulletin of the International Railway Congress Association*—Brussels, April 1960, Vol. XXXVII No. 4.
7. Electrical Interference Aspect of Buried Electric Power & Telephone Lines; Forrest Woodland, Jr. IEEE Transaction on Power Apparatus & Systems, Vol. PAS-89. No. 2, February 1970, pp. 275–280.
8. Wire or Cable Has Many Faces, Know Them All Before Choosing, Part II, F. Timmons, *EDN,* March 1, 1970, p. 49.
9. *Inductive Coordination—Definitions, Principles & Practices.* Canadian Standards Association's Standards C22.3 No. 3.
10. *Inductive Interference & Its Measurement on Electrified Railways;* A. W. Woodbridge, H. R. J. Klewe, R. O. Kapp. Adv. Paper. Institute of Railway Signal Engineers, London, September 28, 1962.
11. *A Manual of Ground Resistance Testing;* James G. Biddle Company, Publication No. 25-T-1952.
12. *Planning for Railroad Electrification;* Bass & Gilman, IEEE New York Section, Transportation Division, Land Technical Group, March 11, 1970.

13. Railroad Electrification: Past, Present & Future; G. D. Friedlander, *IEEE Spectrum,* July, August, Sept., 1968.
14. Recommended Guide for Measuring Ground Resistance & Potential Gradients in the Earth; AIEE No. 81, 1962.
15. Some of the Fundamental Aspects of Ground Resistance Measurements; E. B. Curdts, AIEE Transactions Vol. 77, Part 1, 1958, p. 760.
16. Track & Lineside Signaling Circuits in A.C. Electrified Areas; J. E. Candler, G. I. Foster, W. M. Sweetenham, *The Institute of Railway Signal Engineers* No. 17, 1962.
17. *Western Union Engineering Bulletins:*
    - 1A—*Inductive Coordination—Theory of Induction*
    - 4A—*Inductive Coordination—Experimentation*
    - 5B—*Inductive Coordination—Collection of Engineering Data*
    - 89A—*Inductive Coordination—Shielding*

Note: See AREA Bulletin 646, January–February 1974, for additional references.

Report of Committee 4—Rail



V. E. Hall, *Chairman*

R. M. Brown,
Vice Chairman

A. B. Merritt, Jr.,
Secretary

R. F. Bush
R. C. Postels
W. J. Cruse
W. S. Lovelace
G. H. Maxwell
R. E. Gorsuch
E. H. Waring
D. H. Stone
L. A. Logsdon
V. R. Terrill

J. I. Adams
B. G. Anderson
S. H. Barlow
D. A. Bell
R. E. Catlett
R. D. Claborn
J. T. Collinson
L. S. Crane
P. K. Cruckshank
Daniel Danyluk
A. R. DeRosa
Emil Eskengren
R. C. Faulkner
M. A. Ferguson
B. R. Forcier
E. T. Franzen
W. H. Freeman
A. H. Galbraith
R. G. Garland
G. H. Geiger
W. J. Gilbert
R. L. Gray
J. H. Greason, Jr.
R. E. Haacke
C. C. Herrick
W. H. Huffman
T. B. Hutcheson
A. V. Johnston
K. H. Kannowski
R. R. Lawton
H. F. Longhelt
J. F. Lyle
T. C. MacKenzie
Ray McBrian (E)
J. L. Merritt
B. R. Meyers (E)
F. W. Michael
C. E. Morgan (E)
G. L. Murdock
B. J. Murphy
B. F. Overbey
C. F. Parvin
C. O. Penney
G. L. P. Plow (E)
S. H. Poore (E)
J. M. Rankin
M. S. Reid
I. A. Reiner
R. B. Rhode
H. L. Rose
C. N. Scott
L. H. Shisler
W. A. Smith
B. D. Sorrels
C. L. Stanford
Erich Thomsen
G. S. Triebel
M. S. Wakely
C. E. Weller
H. M. Williamson
M. J. Wisnowski
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman, and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

1. AREA—Industry Joint Subcommittee on Welded Rail.
No report.

2. Collaborate with AISI Technical Subcommittee on Rail and Joint Bars in Research and Other Matters of Mutual Interest.
No report.

3. Rail Failure Statistics.
No report.

4. Up-date Data on Methods and Equipment for Making Welding Repairs to Rail.
No report.

5. Rail Research and Development.
   Advance progress report was published in Bulletin 649, September–October, 1974.

6. Joint Bars: Design, Specifications, Service Tests, Including Insulated Joints and Compromise Joints.
   No report.

7. Laying of Continuous Welded Rail.
   No report.

8. Maintenance of Continuous Welded Rail.
   No report.

9. Standardization of Rail Sections.
   Progress report, presented as information .... page 407

10. Effect of Heavy Wheel Loads on Rail.
    No report.

11. Field Welding.
    No report.

12. Continuous Welded Rail Field Handbook.
    No report.

COMMENTARY

As indicated by the assignments listed above, Committee 4 has been completely restructured. This was done as a result of the Board of Direction decision to merge Committees 4 and 31 which became effective at the close of the Technical Conference on March 20, 1974, at which time, Committee 31 lost its identity.

Prior to merger, one of the major concerns of Committee 31 was the status of the non-railroad Associate Members of their group that represented a lot of talent and had been very helpful to them. Committee 4 had no Associate Members but maintained a relationship with the AISI Technical Subcommittee through our Subcommittee 2. Instead of having Associate Members on Committee 4, we established a new Subcommittee 1 that has 19 Rail Committee members and 17 non-railroad technical representatives (not sales oriented) from the AISI Technical Subcommittee, welding contractors, suppliers of field welding, rail grinding and rail testing contractors. The non-railroad members have a chairman whose function is to operate this Joint Committee in conjunction with the Chairman of Committee 4. This group has seven assignments that are being progressed involving welded rail and related matters that are not presently listed as separate numbered assignments.

The Committee on Rail,
V.E. Hall, *Chairman.*

Report on Assignment 9

Standardization of Rail Sections

E. H. Waring *(chairman, subcommittee)*, R. M. Brown, R. D. Claborn, P. K. Cruckshank, W. J. Gilbert, V. E. Hall, W. H. Huffman, F. W. Michael, B. J. Murphy, B. F. Overbey, R. C. Postels, J. M. Rankin, I. A. Reiner, G. S. Triebel.

During 1973, Subcommittee 9 secured from Canadian and United States rail mills a summary of the tonnage rolled and tonnage shipped in each rail section. A tabulation of that information is presented below.

It will be noted that 957,096 tons or 84.57% of the total rail rolled in 1972 was in the sections to which it is recommended that purchases of new rail be limited, while 843,511 or 85.44% of the total rail shipped directly to North American member roads was in recommended sections.

During 1974, Subcommittee 9 has secured from the AISI Technical Committee on Railroad Materials a summary of the tonnage of rail shipped from Canadian and United States steel mills to North American Railroads. A tabulation of this information is also presented below.

It will be noted that 771,765 tons or 83.82% of the total shipped in 1973 was in sections to which it is recommended that purchases of new rail be limited.

We have been advised that the information shown for the year 1972 and previous years contain tonnage that should not have been included and in the future we will only be provided information in the same format as shown for the year 1973.

These reports are submitted as information.

Rail Rolled and Shipped By Weight and Sections
1972

		Rolled		*Shipped*	
Weight	*Section*	*Tons*	*% Total*	*Tons*	*% Total*
140*	AREA	51,461	4.55	47,812	4.84
136*	AREA	260,318	23.00	202,247	20.49
133	AREA	65,696	5.80	47,369	4.80
132*	AREA	321,254	28.38	296,282	30.01
131	AREA	820	0.07	540	0.06
130	AREA	4,208	0.37	3,829	0.39
122	CB	36,114	3.19	32,796	3.32
119*	AREA	68,706	6.07	56,281	5.70
115*	AREA	225,853	19.96	214,955	21.76
112	AREA	3,784	0.33	3,255	0.33
105	DL	302	0.03	259	0.03
100	ARA-A	45,893	4.06	39,364	3.99
100*	AREA	12,830	1.13	11,543	1.17
100	ASCE	4,496	0.40	4,072	0.41
90*	ARA-A	16,674	1.47	14,391	1.46
90	ASCE	895	0.08	823	0.08
85	ASCE	8,776	0.78	8,101	0.82
80	ASCE	3,712	0.33	3,385	0.34
Total		1,131,792	100.00	987,304	100.00

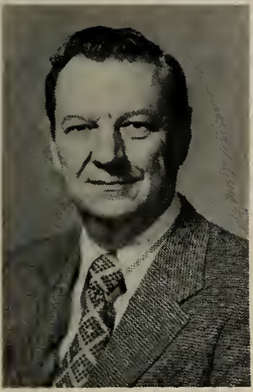
CONSOLIDATED REPORT OF RAIL SHIPPED TO NORTH AMERICAN RAILROADS FROM NORTH AMERICAN RAIL-PRODUCING MILLS IN 1973, BY WEIGHT AND SECTION

Weight	*Section*	*% Total*	*Tons Shipped*
140*	AREA	6.51	59,939
136*	AREA	12.73	117,168
133	AREA	8.61	79,279
132*	AREA	39.01	359,209
131	AREA	0.06	510
130	P. S.	0.04	374
130	AREA	0.11	976
122	CB	2.32	21,376
119*	AREA	5.16	47,477
115*	AREA	18.07	166,349
112	AREA	0.18	1,684
100	ARA-A	4.06	37,394
100	ARA-B	0.07	654
100*	AREA	2.00	18,454
90*	ARA-A	0.34	3,169
85	ASCE	0.47	4,314
85	CPR	0.11	1,001
80	ASCE	0.15	1,420
TOTAL		100.00	920,747

---

* Sections listed on page 4-M-2 of the AREA Manual as those to which it is recommended that purchases of new rail be limited.

Report of Committee 5—Track



L. A. Pelton, *Chairman*

B. E. Pearson,
Vice Chairman

C. L. Gatton, *Secretary*

A. J. Schavet
E. F. Pittman
R. E. Kuston
V. M. Schwing
C. N. King
G. E. Fischer
C. W. Morrison
A. B. Hillman, Jr.

C. D. Archibald
R. C. Arnlund
T. L. Biggar
W. R. Bjorklund
R. G. Bolduc
J. O. Born
S. W. Brunner
M. E. Byrne
R. E. Clemons
W. E. Cornell (E)
C. M. Cowles
E. D. Cowlin
W. G. Crone
D. E. Crouser
D. R. Davis
W. B. Dwinnel
A. G. Ellefson
E. E. Frank
R. G. Garland
C. H. Gaut
S. W. George
L. R. Hall
R. J. Hardenbergh
J. R. Harris
C. N. Harrub, Jr.
E. E. Howard
R. G. Huston
W. D. Hutchison
L. H. Jentoft (E)
D. L. Jerman
R. J. Jones
L. C. Kerns
L. T. Klauder
G. G. Knupp
M. E. Kornspan
A. J. Kozak
J. R. Masters
G. H. Maxwell
C. J. McConaughy
L. P. McKenna
C. R. Merriman
N. R. Meyer
T. C. Netherton
B. W. Nyland
W. B. O'Sullivan
M. Palmer S.
J. Payne
G. H. Perkins
C. E. Peterson (E)
S. H. Poore (E)
W. P. Pope
L. E. Porter
B. Post
R. P. Rasho
L. L. Rekuch
E. C. Rudolph
J. M. Salmon, Jr. (E)
J. A. Saunders
R. N. Schmidt
N. J. Skoutelas
D. E. Staplin
R. L. Teeter
R. E. Tew
A. C. Trimble
K. H. von Kampen
W. J. Wanamaker
R. A. Westin
M. E. Wilson, Jr.
E. R. Wiltz
A. Wisman
A. J. Zierow

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

2. Track Tools.
No report.

3. Revision of Portfolio of Trackwork Plans and Specifications.
No report.

4. Track Design.
No report.

5. Turnout and Crossing Design.
Progress report, presented as information .... page 410

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

6. Track Construction.
   No report.

7. Track Maintenance.
   No report.

8. Criteria for Track Geometry Design as Related to Modern Equipment.
   Brief progress statement, submitted as information .... page 413

THE COMMITTEE ON TRACK,
L. A. PELTON, *Chairman.*

Vern Calvin Hankins
1909-1974

Vern Calvin Hankins, retired assistant director, maintenance planning, Burlington Northern Inc., passed away at Renton, Washington, on January 17, 1974.

Born at Peoria, Illinois, on March 30, 1909, Mr. Hankins began his railroad career with the former Great Northern Railway on June 16, 1930, as a weed burner in Montana. He rose through the ranks in track maintenance, holding positions of division roadmaster, assistant superintendent maintenance and engineering, general maintenance supervisor, and engineer, maintenance of way, to name a few.

He joined the American Railway Engineering Association in 1949. He had served as an active member of Committee 5 since 1966.

Mr. Hankins is survived by his wife, Margaret, Renton; a son Roger M., Baton Rouge, Louisiana; and a daughter Marion V., Boulder, Colorado.

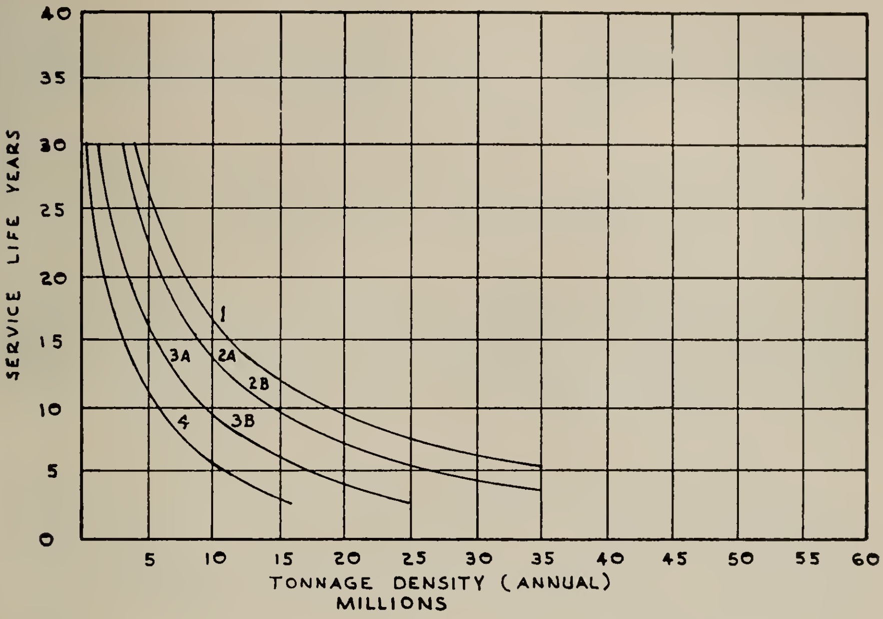
Report on Assignment 5

Turnout and Crossing Design

C. N. KING *(chairman, subcommittee)*, R. G. BOLDUC, A. G. ELLEFSON, R. J. JONES, R. E. KUSTON, L. P. MCKENNA, J. R. MASTERS, G. H. PERKINS, L. E. PORTER, L. L. REKUCH, A. J. SCHAVET, N. J. SKOUTELAS, E. R. WILTZ.

(A) TYPES OF CROSSING FROGS IN USE AS RELATED TO SPEED, TONNAGE, ETC.

Most of the discussion to date has been based on a survey originating during 1968. Replies from various railroads indicated types of crossing frogs in use and in some cases gave data for making a choice. However, the survey was not quantitative and, therefore, contains little more than a variety of opinions. A meaningful survey must first show the quantities for each type in service and also indicate some average annual traffic densities for the various types. Aside from those now in service, it would also be necessary to show quantities of replacement types which would displace those types now in service.



1 MANGANESE STEEL INSERT, INTEGRAL BASE,
DEPTH HARDENED.
2A MANGANESE STEEL INSERT, DEPTH HARDENED.
2B SOLID MANGANESE STEEL, INTEGRAL BASE, DEPTH HARDENED
3A MANGANESE STEEL INSERT
3B SOLID MANGANESE STEEL, DEPTH HARDENED
4 SOLID MANGANESE STEEL
5 BOLTED RAIL - 3 RAIL.
6 BOLTED RAIL - 2 RAIL.
7 BOLTED RAIL - SINGLE RAIL

Although speed relates to impact and, therefore, wear on crossing frogs, it is generally an unrecorded and unsubstantiated figure, whereas an average traffic density can easily be established. Therefore, this should in most cases form the only criteria for making a choice. Accompanying is a hypothetical graph similar to a rail wear chart which could be utilized to show this information. However, even a graph of this sort based on experimental data could only be a very general guide due to so many variables at any one location.

A consensus of the subcommittee members is that all types of crossings shown in the Portfolio of Trackwork Plans with the exception of the single- and two-rail crossings may be used in heavy traffic.

(B) Review Taper on Guard Rails Protecting Track Crossing Frogs

A member of the subcommittee has been delegated to put together the material as now shown in the Portfolio. This will form a basis for study and recommendations to be made during future meetings.

(E) Improvement to Manganese Insert Frog Design

Plan 600A-73 criteria for railbound manganese steel frogs re-introduced into the Portfolio covers the 600 series of frogs. Additional proposed changes are being further studied.

Other pertinent subjects which the subcommittee is currently studying are as follows:

1. *Double Slip Switch*

The Southern Railway submitted a problem having to do with the difficulties encountered in throwing of movable-center switch points. This was diagnosed as insufficient allowance for overthrow which should be designed into the heel block assemblies. The necessary revisions on the appropriate plans will be prepared for submission to the subcommittee.

2. *The "Standard Turnout Plans" Located in the Front of the Portfolio*

It was requested that consideration be given to incorporating these plans into the body of the Portfolio, and eliminate the separate portion. The consensus of the subcommittee was to leave as is. It should be pointed out, however, that whenever revisions are to be made to plans, the changes only become complicated when the "Standard Plan" series are involved, due to repetition being required and to lack of space on overcrowded plans. Further consideration and discussion will be given to the idea of merging these plans.

3. *Adjustable Vertical Switch Rods*

The following note to be inserted on AREA plan 222-62 and sheets 2 of all the "Standard Plan" series:

"Adjustable vertical switch rods approved by the purchaser may be used place of horizontal switch rods."

4. *Flangeway Contour*

A revision to plan 600-B and appropriate sheets for the "Standard Plan" series to show for the top corner radius of the flangeway contour (both gauge and guard sides) an alternate ⅝-inch radius applying only to rail sections in groups 1, 1A, 1B, 1C, 3 and 3A (Ref. plan 1001-55) or to any new rail sections not yet included in the reference plan, but which have similar compound curves for the running surfaces of the head.

5. *Items Being Considered for Further Study*

Contour planing for switch points; criteria for top cut of switch points; review placement of switch rods in switches; review placement of gauge plates in switches; frog throat design—taper in place of radius; depressed heel for frog inserts; fasteners—elastic stop nuts and tension fasteners; point of frog—the point may be dropped to ¼ inch below frog surface in place of present 3/16 inch; wing rail easer—to provide ramp on wing side for easement of wheel transfer; gauge widening—eliminate gauge widening in turnout curves; turnouts—use of flat tie plates throughout turnout and in advance of switch, this eliminates alternately vertical and canted conditions of closures, etc.; and guard rails—review tapers and lengths.

Report on Assignment 8

Criteria for Track Geometry Design as Related to Modern Equipment

A. B. HILLMAN, JR. *(chairman, subcommittee),* R. E. BUNKER, W. B. DWINNELL, D. L. JERMAN, L. T KLAUDER, N R. MEYER, B. E. PEARSON, W. B. O'SULLIVAN, L. A. PELTON, B. POST, R. E TEW, W J. WANAMAKER, M. E. WILSON.

Both assignments of Subcommittee 8, namely, (a) Special Requirements of Track Construction and Maintenance Due to Operation of Equipment with High Centers of Gravity, and (b) Investigation of Minimum Tangent Required Between Reverse Curves, are included in Task 1 of Phase II of the Track Train Dynamics Program. Your subcommittee will keep in touch with the Track Train Dynamics Program and report on progress with respect to the above subjects.

Report of the Special Committee on Scales

F. D. Day, *Chairman*

V. H. Freygang,
Vice Chairman

M. R. Gruber, Jr.,
Secretary

L. L. Lowery
E. Szaks
B. F. Banks
N. A. Wilson
O. T. Almerode

R. F. Beck
R. O. Bradley
R. T. Brumbaugh
H. E. Buchanan
E. W. Buckles
G. H. Chabot
J. L. Dahlrot
R. H. Damon, Jr.
T. A. DeAlba
O. C. Denz
J. L. Finnell
J. E. Foreman, Jr.
G. F. Graham
J. A. Hawley
I. M. Hawver
L. J. Held
A. L. Hunter
D. K. Johnstone
D. E. Keefer
S. H. Levinson
V. L. Lowery
E. J. Micono
N. S. Patel
R. E. Park
B. H. Price
W. H. Rankin
S. H. Raskin
A. E. Robinson
J. J. Robinson
K. D. Tidwell
J. N. Todd
L. J. Walker
P. C. White
J. Zaenger

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

The revision of the Scale section of the Manual was completed in 1973 and published as a separate pamphlet, Part S.

In 1974 the AAR adopted the Manual Part S and a new 1974 "Brown Book" has been published for the guidance of consultants, manufacturers, industries and all others interested in acceptable scale construction, maintenance and testing tolerances.

Also in 1974 the National Conference of Weights and Measures adopted and incorporated into the National Weights and Measures Handbook 44 the railroad test tolerances, making the provisions of AAR/AREA and Handbook 44 compatible.

Continuing minor modifications of the Manual Part S are being reviewed for action in 1975.

1. Location of Scales for Railroad Coupled-in-Motion Weighing.

   A preliminary report has been written and circulated for comment. Final report is expected for late 1975 publication.

2. Survey of All Scales in America Used for Weighing Railroad Cars.

   The first tabulation of 5404 scales has been completed. Computer print-outs are presently out to the railroads for correction and updating.

3. Statistical Data for Coupled-in-Motion Weighing and Testing.
   Data from 24 tests involving over 2000 weights have been collected and are consolidated for a final report.

4. Handbook 44 Joint Study with State Weights and Measures Officials.
   The subcommittee is working with the National Bureau of Standards technical scale people to revise for joint adoption certain additional test procedures and a uniform inspection procedure.

The Special Committee on Scales,
F. D. Day, *Chairman.*

Report of Committee 3—Ties and Wood Preservation

G. H. Way, *Chairman*

C. P. Bird,
Vice Chairman

R. G. Zietlow, *Secretary*

F. J. Fudge
J. T. Skerczak
R. J. Shelton
L. C. Collister
K. C. Edscorn

J. W. A. Ager
H. C. Archdeacon
W. F. Arksey
A. B. Baker
S. L. Barkley
W. W. Barnette
R. S. Belcher (E)
G. W. Brenton
R. G. Brohaugh
C. A. Burdell
C. S. Burt (E)
M. J. Crespo
E. M. Cummings
D. L. Davies
R. F. Dreitzler
I. A. Eaton
D. E. Embling
W. E. Fuhr
B. J. Gordon
J. K. Gloster
D. C. Gould
R. D. Hellweg
J. E. Hinson
R. P. Hughes (E)
R. G. Huston
G. P. Huhlein
L. W. Kistler (E)
M. A. Lane
G. H. Nash
T. J. O'Donnell
J. A. Peebles
R. B. Radkey
H. A. Richardson
R. H. Savage
K. W. Schoeneberg
G. D. Summers
R. C. Weller
F. M. Whitmore
J. L. Williams
E. L. Woods
C. W. York, Jr.

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

2. Cross and Switch Ties.
No report.

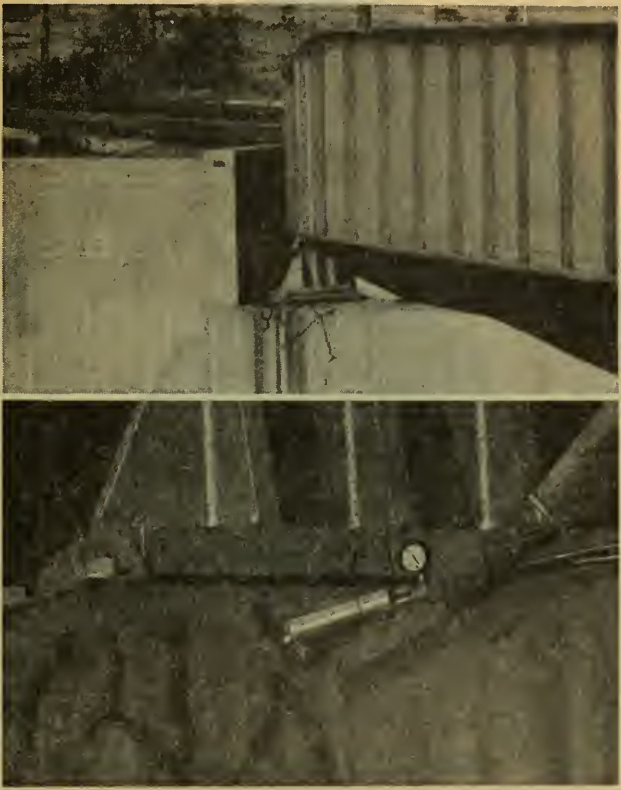
3. Wood Preservatives.
No report.

4. Preservative Treatment of Forest Products.
No report.

5. Service Records of Forest Products.
The annual tie renewal statistics as compiled by the Economics and Finance Department, AAR, were published as an advance report in Bulletin 649, September–October 1974. Also published in that Bulletin as an advance report was the final report on the decay and termite control investigation following an inspection of specimens after 180 months of exposure.

6. Collaborate with AAR Research Department and Other Organizations in Research and Other Matters of Mutual Interest.
No report.

The Committee on Ties and Wood Preservation,
G. H. Way, *Chairman.*



CONCRETE PROBLEMS?

OSMOSE EPOXY INJECTION MAY BE THE ANSWER

Osmose, the Company synonymous with timber bridges, has now diversified into concrete bridge maintenance, specializing in "welding" structural cracks.

This proven method consists of • ANALYSIS • CLEANING • SEALING • CONTROLLED PRESSURE INJECTION • DETAILED INSPECTION REPORTS

Restores structural integrity under traffic.

OSMOSE **RAILROAD DIVISION**
4915 Monona Drive
Madison, Wis. 53716
608/222-6800

MEMBER
RPI
RAILWAY
PROGRESS
INSTITUTE

We've a lot going for you.

We call it "The Big Green," and it's all go. For you.

It's what we put into every one of our railway products to give you the big return you want and need, to meet required standards on your roads.

Our anchors, rail joints, heaters and rail and flange lubricators give you the edge in every major investment consideration.

They're built to give you longer, trouble-free performance.

They're built for fast and easy installation.

They're built to save manhours, reduce downtime, keep your trains rolling.

That's where the real savings dollars are. That's where the big return is. Has been. Always will be.

That's why you should talk to your Portec man before you invest in rail anchors, joints, heaters or rail and flange lubricators.

The big green. It's as close as your phone.

RAILWAY PRODUCTS DIVISION
The better product producing people.

PORTEC inc.
300 Windsor Drive • Oak Brook, Illinois 60521
(312) 325-6300 • TWX No. 910-651-0212

A tradition of service . . .

- **Water Treatment Chemicals Protecting Diesel Cooling Systems and Steam Generators**
- **Fuel Oil Additives**
- **Pollution Control Chemicals and Consulting Services**

NALCO CHEMICAL COMPANY
2901 BUTTERFIELD ROAD • OAK BROOK, ILLINOIS 60521

NALCO Trademarks of Nalco Chemical Company

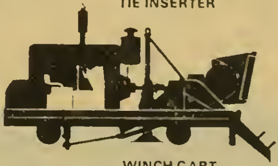
NALCO

Communication:

MANNIX

has changed its identification

TIE INSERTER



WINCH CART

SHOULDER BALLAST CLEANER

LORAM

IS THE

NEW NAME

ON OUR

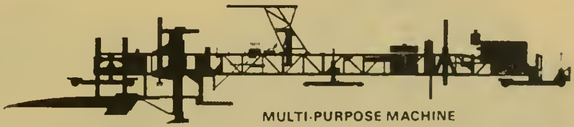
NEW PLANT

AND ON THE

PERFORMANCE PROVED

EQUIPMENT WE DESIGN AND BUILD

AUTOSLED



MULTI-PURPOSE MACHINE

AUTOTRACK WITH PLOW AND SLED

THE ANSWER TO YOUR 1975 TRACK REHABILITATION PROGRAM

MEMBER RPI RAILWAY PROGRESS INSTITUTE

LORAM RAILWAY MAINTENANCE EQUIPMENT FOR:

• Shoulder Ballast Cleaning • Raising Track • Resurfacing • Reballasting • Replacing Ties • Undercutting • Ballast Cleaning • Rail Grinding Single or Multiple track – Mainline or Yard tracks

CONTRACT, SALE or LEASE

FOR FULL DETAILS, OR SHOWING OF OPERATING FILMS, WRITE OR CALL TODAY

LORAM CONSTRUCTION INC.

MAINTENANCE of WAY DIVISION

3900 Arrow Head Drive
Hamel, MN 55340 U.S.A.
Phone (612) 478-6014
Telex 29-0391, Cable, LORAM

RAILROAD TRACKS
designed, constructed
and completely maintained

ROBT. L. DEPRIZIO
& ASSOCIATES INC.

RAILROAD CONSTRUCTION

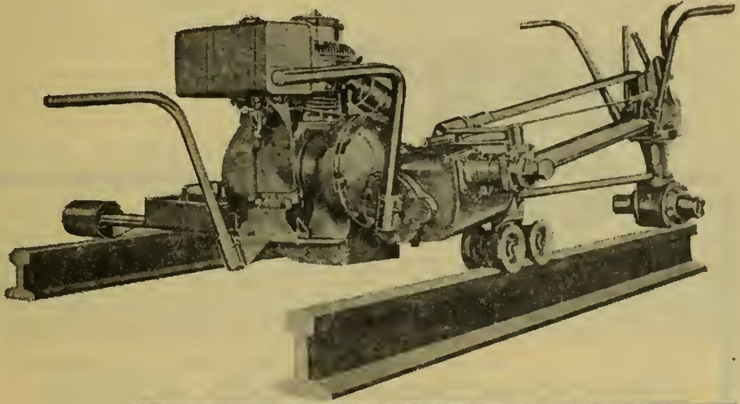
10625 FRANKLIN AVE.
FRANKLIN PARK

455-4400

Not Associated With V. N. Deprizio Construction Company

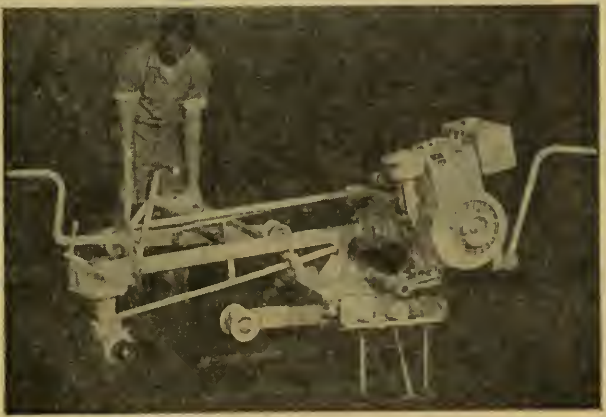
Safetran

MODEL C
TRACK WRENCH
mounted on a
UNIVERSAL TRAVERSE CARRIER



The Industry's Best Buy...

- Lightweight
- Powerful
- Full 360° Rotation
- Set-off Pedestal
- One Man Operation



For operating data and specifications
see SAFETRAN M/W CATALOG—Section 16-C

Safetran Systems Corporation
7721 National Turnpike • Louisville, Ky. 40214 • (502) 361-1691

KERITE CABLE

For dependability in actual use, no other cable matches Kerite. We believe you will be impressed by the evidence.

MEMBER RPI

THE KERITE COMPANY

PRINCIPAL OFFICES: Boston; Chicago; New York; Philadelphia; San Francisco; and Seymour, Connecticut • Sales Representation throughout the United States. A subsidiary of Harvey Hubbell Incorporated.

DAYS KERITE

it's the **KERITE** *insulation that makes the difference*

TIE HANDLER from RTW...

with 24-foot-reach articulating boom!

Lifting capacity—1500 lbs. at 12′6″ to 750 lbs. fully extended.

- New rotating deck design ...no adjustments needed
- Thermostatic controlled oil temperature in hydraulic circuit
- Low maintenance
- Hydrodynamic plus mechanical brakes... on all four wheels

Many other features for high production, low maintenance. Choice of two other tubular-type booms (all interchangeable): Fixed 24-ft., and manually adjustable 18-24-ft. From RTW, the people with the longest experience in tie handling. Get full details today. Call (215) 739-4281.

RTW

OTHER RTW MAINTENANCE EQUIPMENT • Switch Grinders • Cross Grinders • Surface Grinders • Rail Drills • Tie Handlers
RAILWAY TRACK-WORK CO. 2560 East Tioga St., Philadelphia, Pa. 19134
Agents: Chicago—ESCO Equipment Service Co. • Houston—Service Equipment & Supply Company
Los Angeles—Simkins Company • Louisville—T F Going • St. Louis—R. E Bell Co.
S Plainfield, N J.—Eastern Railroad Equipment Corp • Canada Montreal—Woodings-Canada Ltd

MEMBER RPI

EXPERIENCED SPECIALISTS IN THE REPAIRS OF.... RAILROAD STRUCTURES

Turzillo CORPORATION ™

FOUNDATIONS, UNDERPINNING AND INVESTIGATIONS

AUGERCAST®* Piles — placed without vibration
- For new foundations and underpinning
- Retaining wall piles. Low headroom piles
- Tie-back anchoring system for excavations
- Tension piles and anchors

PRESSURE GROUTING
- BAGPIPE®* Groutainer™ inflatable forming system
- Soil stabilization for arresting settlement of structures
- FIRM-UF® chemical grouting for consolidating soils
- Consolidating masonry bridge abutments and piers

CONCRETE AND MASONRY STRUCTURAL REPAIRS
- Bridges, dams, power plants and dry docks
- Scour repairs
- Tunnel lining repairs
- Repairs to precast, concrete, wood and steel piles

PREPLACED AGGREGATE CONCRETE (PAC)
- Cofferdam seals
- Underwater repairs, piers and abutments
- High density concrete for shielding
- Concrete and masonry structural repairs
- Underwater concrete

ONE-SOURCE MARINE SERVICES
- Inspections above and below water
- Engineering reports of inspections
- Staff of experienced divers to perform corrective repairs
- Submit budget or firm quotes
- Complete the work based on findings or at the direction of Owner's engineering department or consultant

* Covered by U. S. and Canadian Patents

P. O. BOX 155 • BRECKSVILLE, OHIO 44141 • TELEPHONE 216/659-3141
ATLANTA • BALTIMORE • CHICAGO • DETROIT • FT. LAUDERDALE • HOUSTON • JACKSONVILLE
MINNEAPOLIS • OMAHA • SEATTLE • TORONTO • TULSA
AFFILIATES: LEE TURZILLO CONTRACTING CO. • AUGERCAST PILE & FOUNDATION COMPANY
TURZILLO CONTRACTING LTD.

no matter how
you look at it
there is just
one toilet
that stands alone.
one toilet that
has gained
general acceptance
world wide.
one toilet familiar
to all who have ever
flown in an airplane,
traveled in a bus,
sailed in a boat,
or lived in a
recreational vehicle.
the one chemical
retention toilet
now available,
designed especially

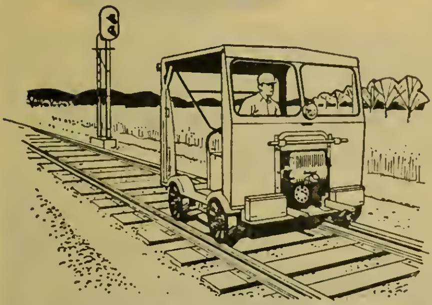
to recognize
the rugged requirements,
for all your
sanitation needs:
locomotive
caboose
work equipment . . .
the Vapor NEWMATIC* toilet,
the toilet used
by more than 40 railroads**
become *more* familiar,
write
Transportation Systems Div.
Vapor Corporation
6420 West Howard Street
Chicago, Illinois 60648
In Canada—
Vapor Canada Limited

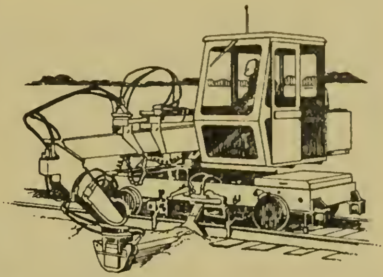
VAPOR CORPORATION
TRANSPORTATION SYSTEMS DIVISION

*TM Monogram Industries, Inc.
**names furnished on request

Fairmont

RAILWAY MOTOR CARS
AND WORK EQUIPMENT





INSPECTION MOTOR CARS
SECTION MOTOR CARS
GANG MOTOR CARS
PUSH CARS AND TRAILERS
HY-RAIL EQUIPMENT
BALLAST MAINTENANCE CARS
WEED MOWERS
MOBILE CRANES
TOW TRACTORS
RAIL GRINDERS
DERRICK CARS
HYDRAULIC POWER TOOLS
TRACK LINERS
TRACK LINING LIGHT
SPIKE DRIVERS
TIE REMOVERS
TIE HANDLERS
RAIL LIFTERS
TIE SHEARS
TIE BED SCARIFIERS
SPIKE PULLERS
TIE PLUG INSERTERS
OIL SPRAYERS
TIE SPRAYERS
TIE INSERTERS

Performance ON THE JOB COUNTS

THESE UNITS ARE ACTUATED EITHER COMPLETELY OR PARTIALLY BY HYDRAULIC POWER

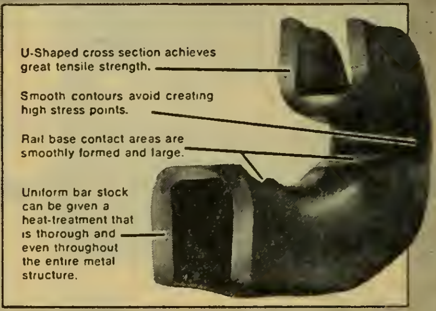
FAIRMONT RAILWAY MOTORS, INC., FAIRMONT, MINNESOTA 56031

When you need one for the road, make it Channeloc®.

The True Temper Channeloc® with massive and unique channel shape provides tremendous gripping power. Its great tensile strength adds years to service life . . . and saves replacement costs.

Channeloc bar stock is uniformly thick, resulting in even heat-treating to avoid softness or brittleness. The Channeloc design assures ample rail contact surface for maximum holding power. Channeloc is applied easily and quickly with minimum ballast disturbance . . . and can be reapplied to save your road maintenance budget.

True Temper has produced over two hundred million Channeloc Rail Anchors. When you need one, make sure it's Channeloc . . . proven since 1960.


U-Shaped cross section achieves great tensile strength.
Smooth contours avoid creating high stress points.
Rail base contact areas are smoothly formed and large.
Uniform bar stock can be given a heat-treatment that is thorough and even throughout the entire metal structure.

Don't settle for imitations. Only Channeloc is protected by U.S. Patent Nos. 3,102,690 – 3,118,327 – 3,159,198

TRUE TEMPER®

An Allegheny Ludlum Industries Company

SWITCH TAMPERS FOR ALL YOUR JOBS

UNIVERSAL UYT-2W75 YARD, SWITCH & SPOT TAMPER

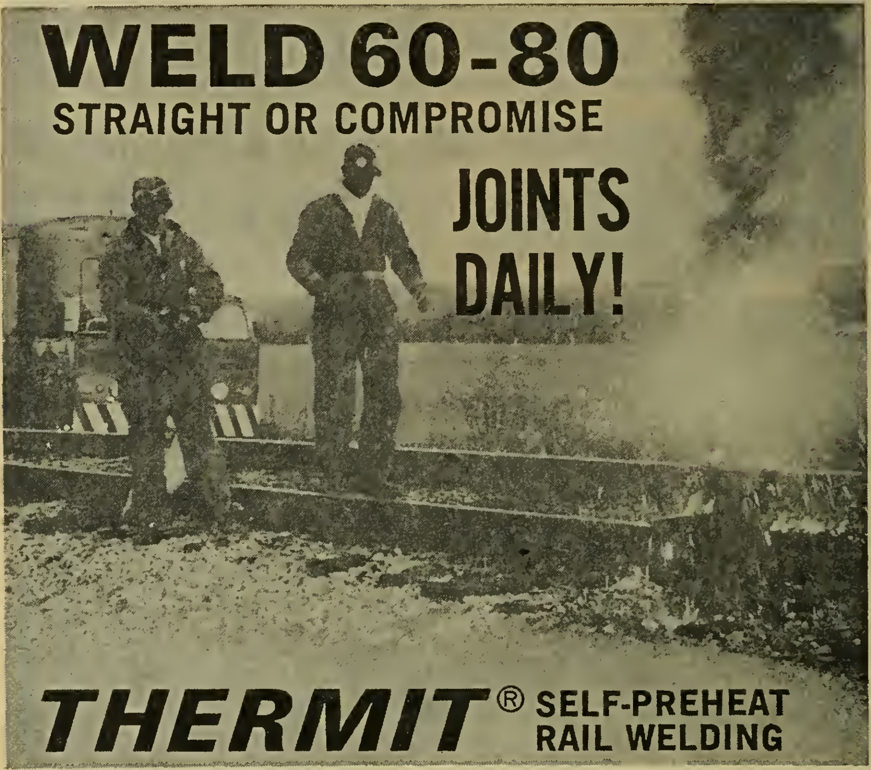
This versatile tamper is a new addition to the popular Plasser Universal line. Even though the UYT 2W75 has a lower original cost, it is equipped with two of the exclusive Plasser four-tool tamping heads with individually tiltable tamping arms, which insures the tamping of every tie through switches and turnouts without the use of outside or ground jacks.

This Universal UYT 2W75 tamper is particularly adaptable for yard work where it has proven itself as a money saver. The reasonable price plus its ability to do a fine job tamping switches and doing spot work suggest yard assignment. It can be equipped with automatic lifting and leveling equipment as well as automatic lifting correction with cross level indicator. You should see one of these tampers in service and we will be pleased to make the necessary arrangements for you to do so at your convenience. You will be convinced that it is a superior machine.

PLASSER AMERICAN CORPORATION

PLASSER FOR PERFORMANCE

GENERAL OFFICES & PLANT
2001 MYERS ROAD
CHESAPEAKE, VIRGINIA 23324



THE MODERN IN-TRACK METHOD

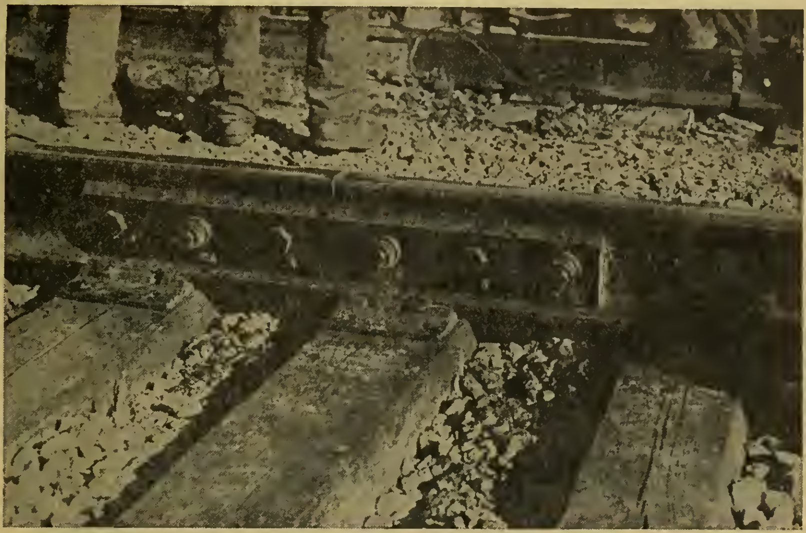
- AUTOMATIC, **ERROR-FREE** PRE-HEATING AND TAPPING OF WELD METALS
- EASY, **COLD** REMOVAL OF RISERS
- MINIMUM GRINDING
- NO EQUIPMENT TO PURCHASE OR LEASE

FREE COMPLETE THERMIT RAIL WELDING DETAILS **PLUS** JOB-SITE DEMONSTRATIONS.

WRITE OR CALL

THERMIT®

THERMEX METALLURGICAL, INC.
LAKEHURST, N. J. 08733 • (201) 657-5781
SALES OFFICES IN MAJOR CITIES



The Allegheny Insulated Rail Joint-

Designed to withstand the heaviest traffic in welded rail

This modern joint cements rail ends in position and thereafter resists all forces imposed by temperature and simultaneous forces of live loads to move them.

This joint makes welded rail truly continuous. It promises you years of service without maintenance costs. It reduces rail and wheel batter to a previously unknown minimum. It employs the safety of steel splice bars. It can be assembled in the shop or field. It has been tested in service and AAR laboratories. It saves you lots of money.

Allegheny Drop Forge Company

Subsidiary of Tasa Corporation

2707 Preble Avenue • Pittsburgh, Pa. 15233

TELEWELD
INC.

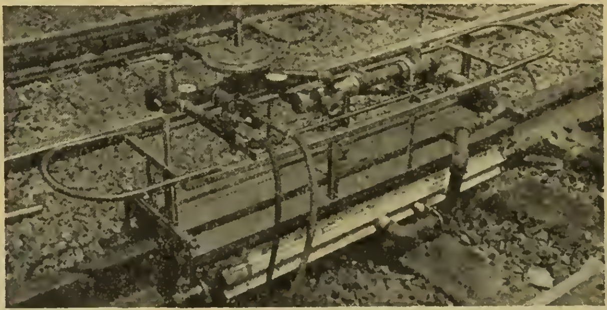
Rail Maintenance Service

Rail End Welding
Rail End Hardening
CWR Joint Normalizing
Frog and Switch Welding

MEMBER
RPI
RAILWAY PROGRESS INSTITUTE

Rail Maintenance Equipment

Custom Manufacturing and Fabrication
Joint Bar Shims
Rail Anchor Shims
Rail End and Frog and Switch
Welding and Grinding Machines
CWR Heating and Cooling Equipment
Rail Flaw Testing Equipment
Telebrineller Portable Hardness Tester



Infra-Red Heater for Curing Adhesive Bonded Rail Joints

TELEWELD INC., 416 NORTH PARK ST., STREATOR, ILL. 61364
Write for details of the TELEWELD process for restoring rail ends.

REGIONAL MEETING

November 6, 1974

Hotel Muehlebach, Kansas City, Mo.

Roadbed Stabilization—Various Methods

By J. B. FARRIS

Engineer Geotechnical Services, Southern Railway System

I wish to thank you for the gracious invitation to address this Regional Meeting of AREA. It is always a pleasure to see old friends, meet new ones and to discuss with this group some of the problems our industry faces. One of these is the problem of repairing roadbed after a failure takes place.

It is not possible this morning to cover all the ways to repair roadbed failures, or all the kinds of failures that occur. What we will do is to inspect some of the things we have done to see why they worked or didn't work.

Before we discuss some of the different means of stabilizing the roadbed, I believe it appropriate to review how the situation we find today came about.

Most of the lines in use today were constructed about 100 years ago, before the development of the principles of soil mechanics. The pressure to advance the railroad must have been very great. The object was to complete the line so that it might begin producing revenue. Cuts and fills were made as narrow as possible with additional drainage and widening of cuts and fills to be accomplished under maintenance conditions. Earth was moved by mules and scrapers, by picks, shovels and wheelbarrows, and in areas where timber was plentiful, primitive trestles were constructed to be filled later. The best compaction was by the mules. Against the background of increasing axle loads and traffic densities of today, we can expect subgrade and embankment failures whenever unusual climatic conditions or increased loading conditions occur. The difference between stability and failure is very small, like a safety factor of 1.01 or 0.99, the only visible difference being that in the first the subgrade is stable and in the second, failure has occurred.

What kind of failures are these that cause our concern?

I have grouped them into two categories for the purpose of this discussion:

1. Subgrade failures (squeezes)
2. Landslides.

SUBGRADE FAILURES

Failure or shear planes in fine-grained soil usually approach a circular or parabolic curve on a cross section. The failed portion of soil rotates along the near circular line. Stability analysis is usually set up assuming the failure plane as a true curve with its origin out in space above and to the side of the earth section. The location of the failure circle on the cross section is extremely helpful in determining the type of correction that would be most effective.

Since borings and other investigative methods are costly and time consuming, it is wise to see if there are field indications that would tip us off to the location and type of treatment needed. Even with the visual indications, the actual depth and position of the failure plane or failed material remains unknown unless subsurface investigations are undertaken.

The sketches accompanying this report are simplified to show some of the various failure forms. These may be considered opposite-handed to the direction shown in the illustration.

Illustrated in Fig. 1 is a condition that permits the right rail to go down, the track to go out of line to the right and the original subgrade in the failure zone to rotate, raising the original subgrade at the shoulder. Sometimes the failed material is extruded like toothpaste onto the shoulder. In some instances the subgrade is squeezed up between the ties. We on Southern often refer to this situation as a "squeeze" although it is known by other names, some of which are unprintable.

A second type of subgrade failure is shown in Fig. 2. The right-hand rail goes down, but the track moves to the left and we find the subgrade pushing up further away on the left. The "squeeze" contains the entire track and a greater area of unstable material than that in the previous illustration and it will take more to repair.

Fig. 3 illustrates a condition common to many subgrade failures where the failure cuts into the ditch line. If the squeeze material is removed from the ditch to restore drainage, the failure is unbalanced. The squeeze promptly moves to restore equilibrium, by again filling the ditch. As the ditch is blocked, more water is turned into the subgrade, soaking and further weakening the subgrade soil so the failed section grows in length along the track. In this illustration, the left rail goes down and the track movement is to the right, indicating again a deep squeeze containing the entire roadbed beneath the tie.

In subgrade failures, it is important to note the rail affected by the failure, the direction of the track movement and the position of the toe of heaving ground. A rule of thumb in considering treatment for subgrade failures is that the distance of the failure plane beneath top of rail is approximately equal to the distance between the near rail and the toe of the heaving ground. This is not very scientific, but it does give one an idea of the extent of treatment needed when considered with other factors involved and is usually on the safe side.

In selecting the methods to stabilize the roadbed, we are often limited in time, equipment and materials available. This is particularly true in emergency situations. The life expectancy of the work based on previous experience as well as initial costs must be considered in selecting the method to be used. The first step is always to correct any drainage problem that may exist in the area.

This simple shallow subgrade failure (Fig. 4) may be eliminated by removing the failed material and replacing it with dense graded aggregate. To do so, we will need to have time to excavate beneath the track to remove *all* failed material to be sure we are in undisturbed ground, backfill and restore track surface to pass trains. Time is a luxury we can seldom afford, often ruling out this approach. Partial removal and replacement is seldom as effective as is pulling the track on ballast.

If the toe of this heave is 4 or 5 ft or more from the rail, we can drive piling, rail, poles, or other materials as close as practical to the end of the ties (Fig. 5). To be successful, we will want the pile to extend into undisturbed material at least twice the depth of the failed material. Longitudinal spacing would be on the order of 5 diameters of the piling and would depend on the nature of the soil being retained.

If the soil is very plastic, it may be necessary to drive two rows on alternate centers to contain the squeeze (Fig. 6).

Where the squeeze is wide and deep, or penetration is limited, we will need to use two or more rows of piles to be effective (Fig. 7). I would hesitate to use piling in this manner at all if the penetration were less than 1.5 times the depth of the failed material.

Applying cement grout into the unstable roadbed has been used in many instances to eliminate squeezes (Fig. 8). It usually does this job very well by filling water pockets. The major objection to its use is that when placed in the subgrade areas, voids in the ballast become filled with cement (making concrete) so that trackwork becomes very difficult. In some places the "hard" spots in the track result in bent rails. For these reasons, we do not use it in shallow squeezes.

In deep subgrade failures (Fig. 9), grouting may be used under carefully controlled conditions but the hazards noted above are still with us. The use of a weak grout can reduce the "hard spots" in the track but at tie level can still mess up track machinery.

In the last few years the use of hydrate lime has come into use to stabilize roadbeds in soils with heavy shrink-swell characteristics. It is being applied in a slurry consisting of about 2–4 lb of lime per gallon of water. A typical application consists of 3 injection points mounted at 5-ft centers being pushed into the roadbed at approximate 5-ft intervals along the track (Fig. 10).

The machine (Fig. 11) that applies the slurry is on a truck with rail wheels that has hydraulic-powered injection points which can penetrate some 8 to 10 ft or more into the subgrade.

The slurry is mixed in a portable tank (Fig. 12) capable of mixing a 20-ton load of lime each mix.

The slurry transport here seen (Fig. 13) behind the injector truck carries a load of slurry to the injector truck to keep a continuous application going.

Dr. James Blacklock of University of Arkansas Graduate School has an evaluation project under way that will hopefully give us some good factual answers in a couple of years on the effectiveness of the lime injection process. In the meantime, some very good results have been reported in some applications while other applications have failed to produce satisfactory results.

The lime treatment is very attractive because it represents possibly the lowest cost per foot of track of any stabilization method available. There are certain details that are apparent at this time, and should be observed.

1. The lime used for the slurry must be fresh hydrate lime meeting requirements of current ASTM Standards.
2. Injection pressures can be critical and need control.
3. Sufficient material must be applied.
4. Injection points must penetrate a sufficient depth to assure distribution of slurry to sound material.
5. It is believed that best results can be obtained in swelling clay soils.

LANDSLIDES

Landslides are responsible for some of the serious roadbed problems. These often result from overloading the slope of the fill, that is, constructing a slope too steep to support itself. Sometimes the material in the slope is weakened by saturation. Most frequently it is the result of flushing fills from the top without benching the old slope.

In Fig. 14, there is a toe break. Only the shoulder of the fill has gone down, but as you see, the lateral support of the roadbed section has been removed. The track is not now affected, but in due course there will be trouble in the track.

It will in all probability degenerate into the condition shown in Fig. 15 where we have a failure break come under the track, in which case the right rail will go down and the track will move to the right. A distinct toe heave will be under way. This slide is shown cutting into natural ground but can be limited only to the fill material.

Fig. 16 shows a slide including the entire track structure. Like the similar condition for the squeeze, the track will go out of line in a direction opposite to the low rail, indicating a more massive movement beneath the surface. We look on this indication as being potentially more troublesome than others.

Some common methods to stabilize landslides include pile driving, grouting and placing an additional berm at the tow which I call "berming." None of these are cheap, but pile-driving time can be measured in days versus weeks or months usually needed for grouting and berming.

Where track is not yet involved, we can control the slide and assure stability of the track by driving a row of piles (Fig. 17). With slide in this position, most of the pile is embedded in good material and so it will act as a cantilever wall to help support the roadbed.

Where our slide cuts to the center of the track (Fig. 18), less of a single pile will be embedded in good material so that if the slide plane cuts very deep, the moving mass will pull the pile on down with it. Also, note—as we move further away from the track, the less the length of pile that will penetrate sound material.

The pile on the slide side, however, will probably have enough toe resistance when tied at the top to an anchor pile driven across the track to act as a retaining structure (Fig. 19). Where a part of the track is involved in the slide, this type construction should be carefully considered. Even when toe restraint fails, the tied pile structure can reduce the danger of rapid failure by controlling the rate of ravelling of the ballast from under the track, giving time to institute more appropriate measures.

Where the entire track is involved (Fig. 20), the tied pile structure is appropriate, provided that toe restraint can be achieved on the slide side. Where toe restraint is questionable, a poured-in-place reinforced concrete pile or pier drilled into rock may be used. Concrete pier retaining structures have been used in many instances, usually as cantilever types where the pile is drilled sufficiently deep into the rock for anchorage; 24 inch and larger diameters have been used.

Application of grout to a slide can provide positive correction. In the shallow type illustrated in Fig. 21, the slide plane is easily accessible to 12- to 15-ft-deep grout points.

On a slide breaking into the track (Fig. 22), grout points are still usually sufficiently deep to obtain positive correction.

However, on slides containing the entire track (Fig. 23), or on higher fills, grout may not reach the sliding plane. We therefore have to consider other measures.

Berming (Fig. 24) may be used in almost any case, but often right-of-way conditions restrict its use. The use of a berm often permits a more accurate determination of a safety factor than the other methods.

Earth or stone may be used in the berm. Embankment should be placed under controlled conditions, to assure its effectiveness (Fig. 25).

A concluding thought—*not mentioned enough* in the text—is drainage. Properly installed and maintained drainage is the best insurance against subgrade failures. A close second is maintaining a uniform crosstie and ballast condition.

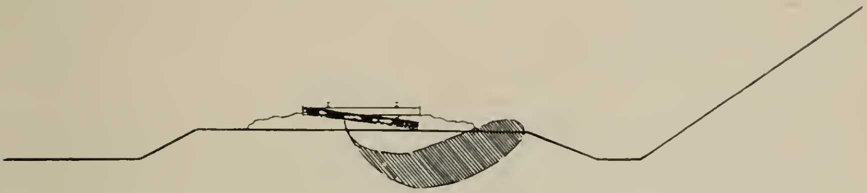


Fig. 1

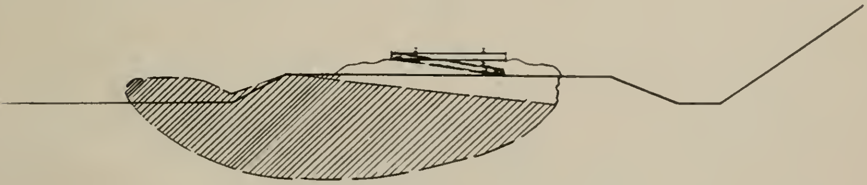


Fig. 2

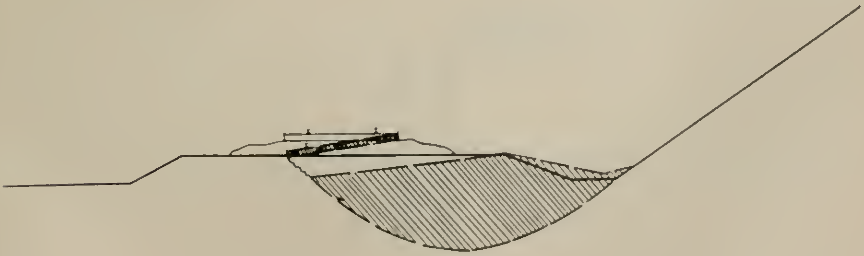


Fig. 3

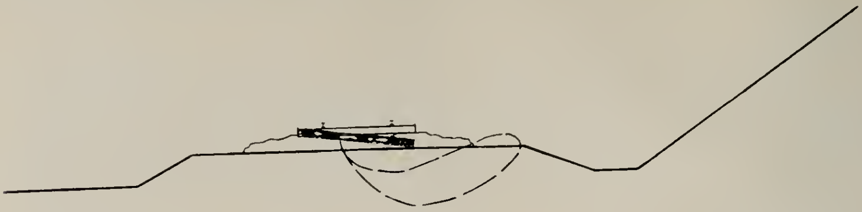


Fig. 4

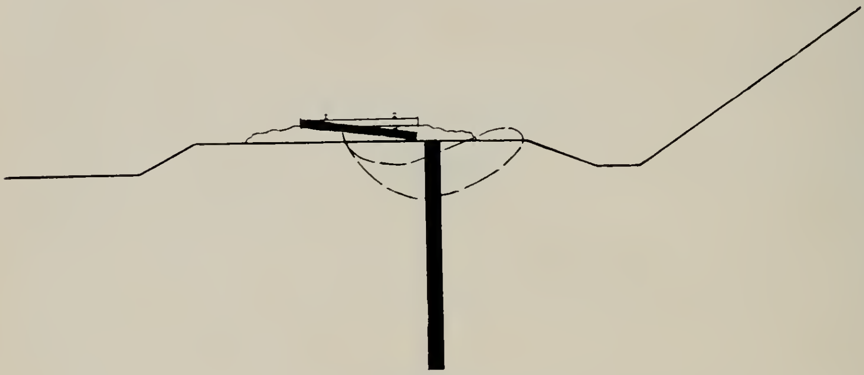


Fig. 5

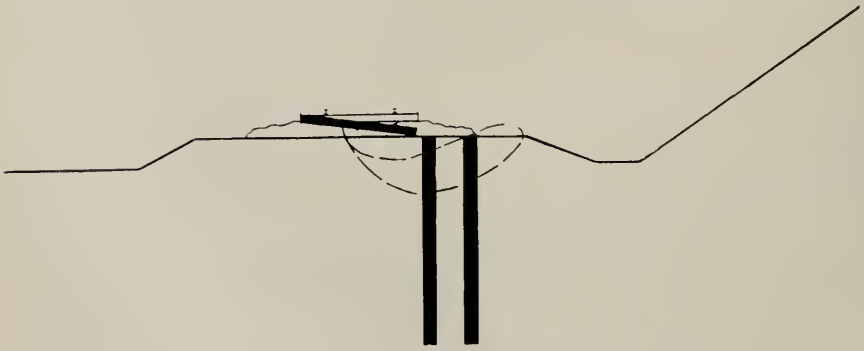


Fig. 6

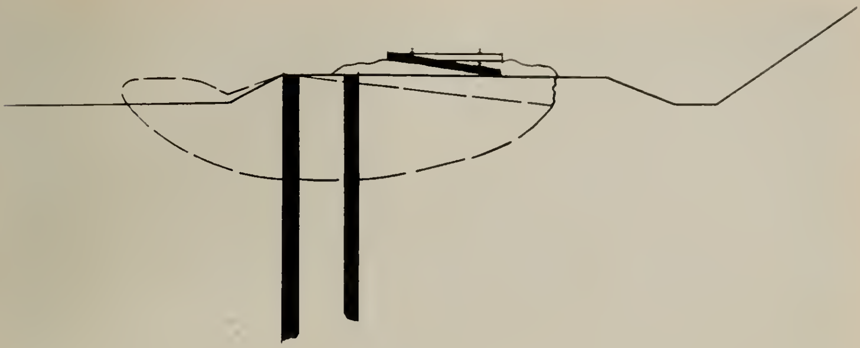


Fig. 7

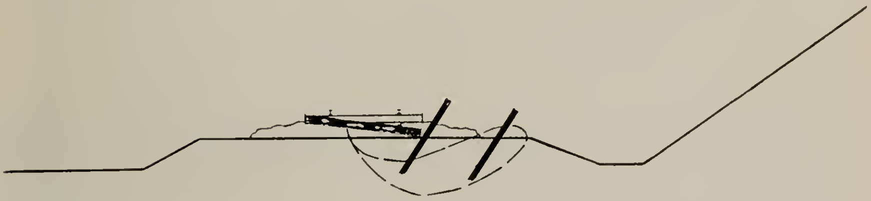


Fig. 8

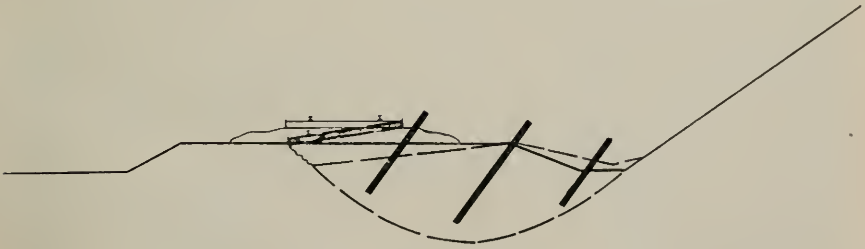


Fig. 9

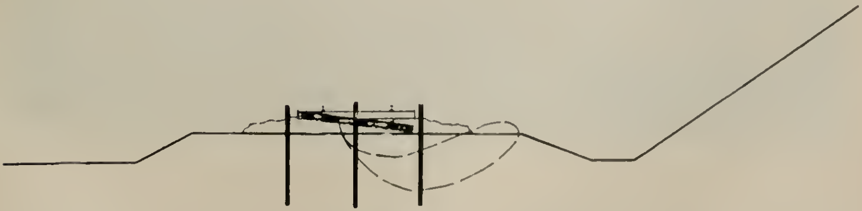


Fig. 10

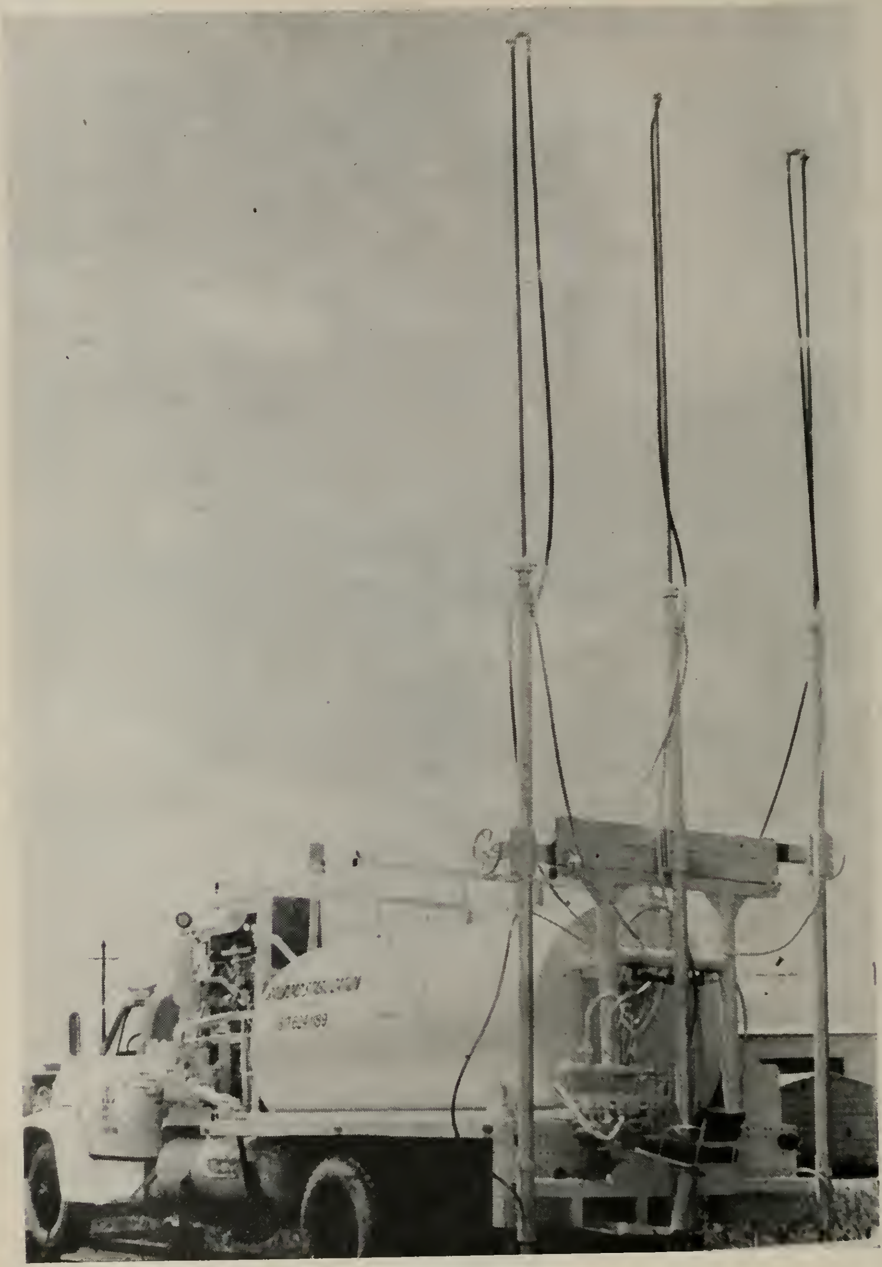


Fig. 11

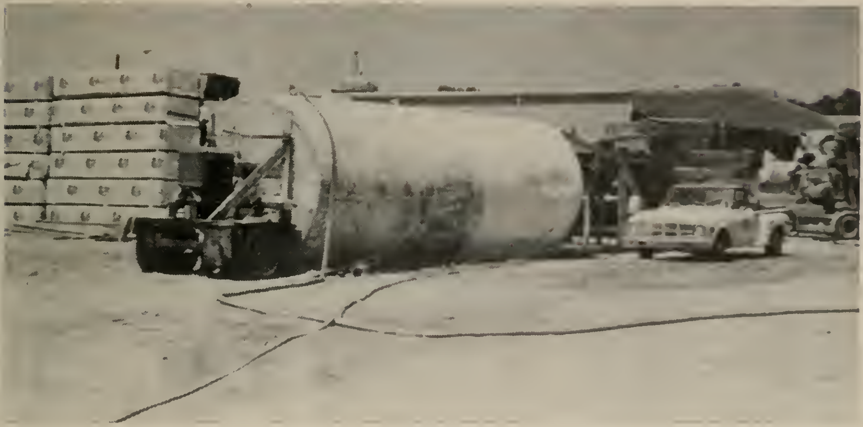


Fig. 12

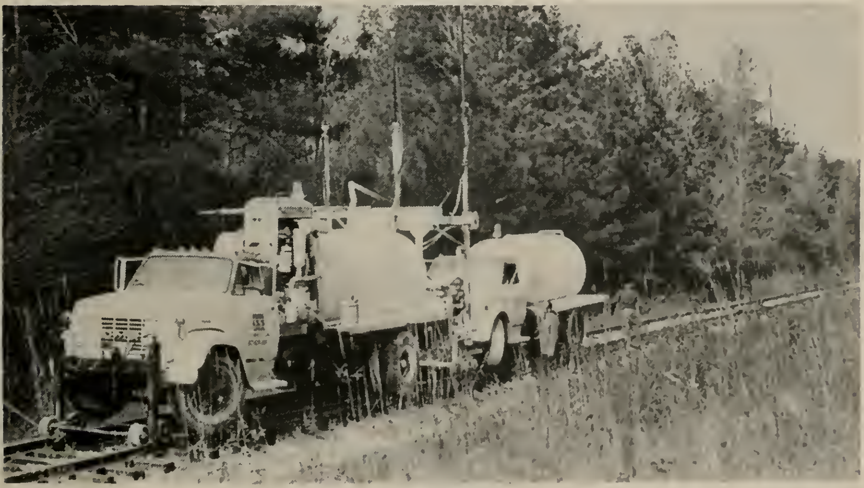


Fig. 13

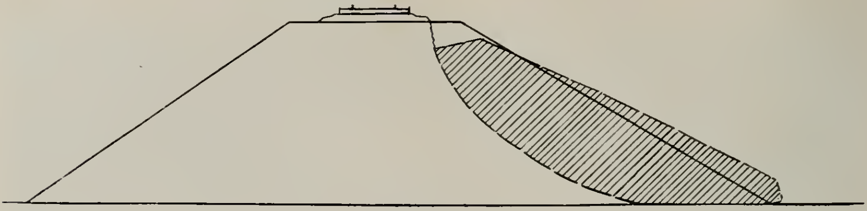


Fig. 14

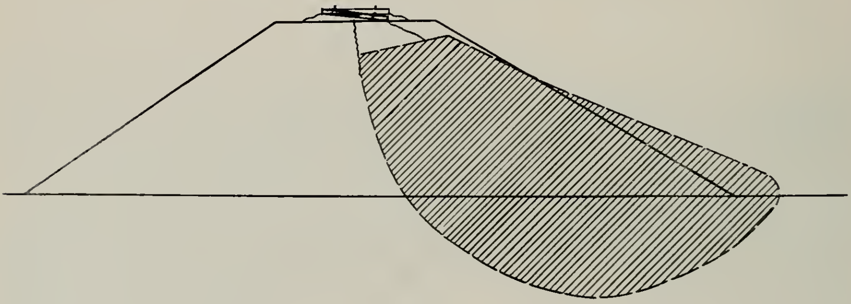


Fig. 15

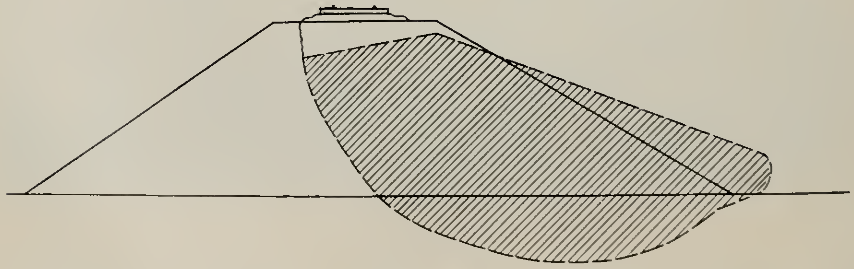


Fig. 16

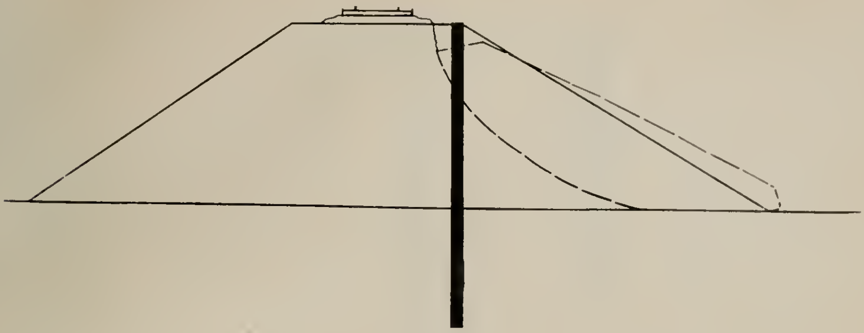


Fig. 17

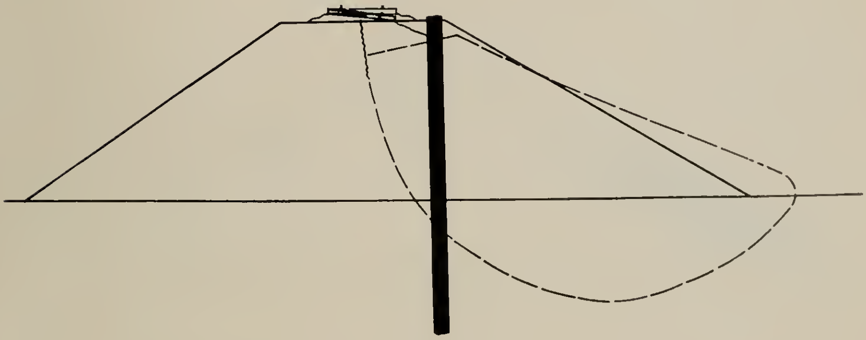


Fig. 18

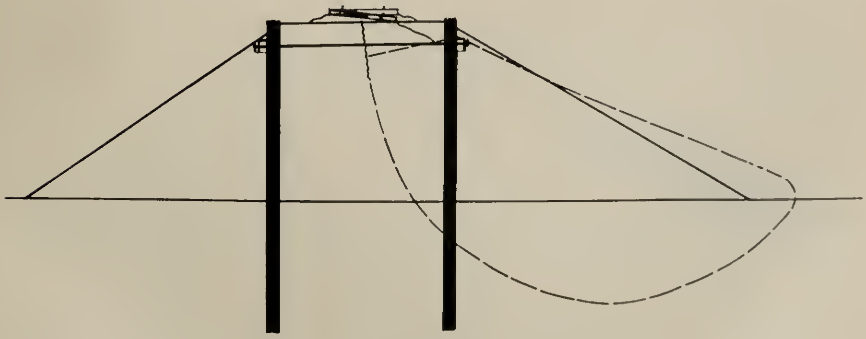


Fig. 19

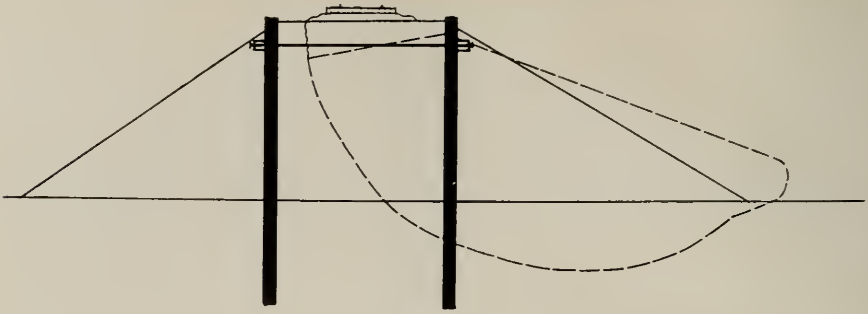


Fig. 20

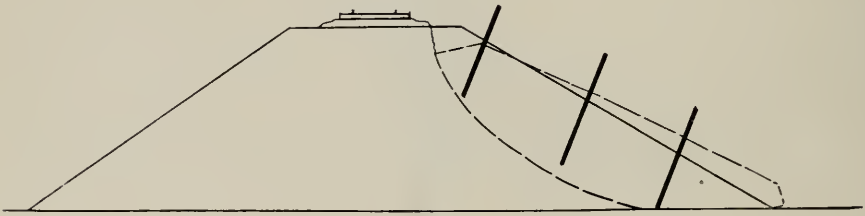


Fig. 21

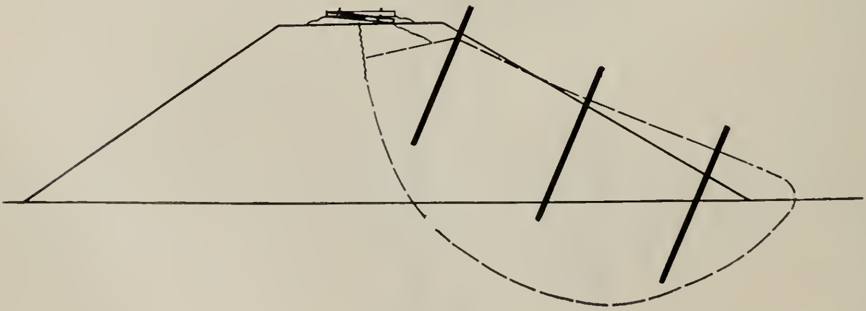


Fig. 22

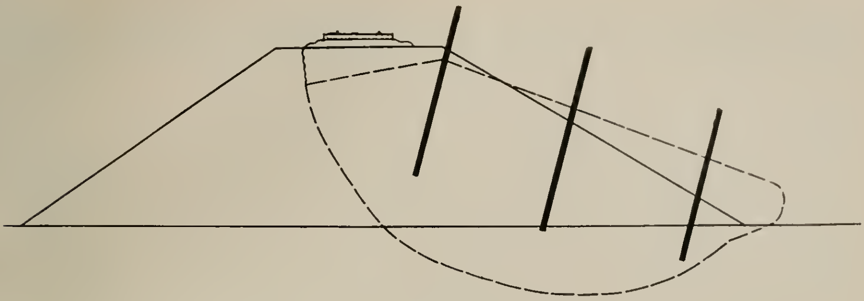


Fig. 23

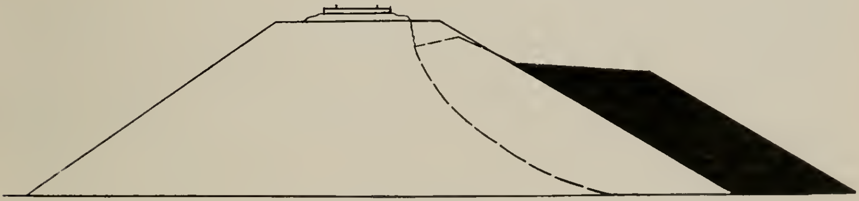


Fig. 24

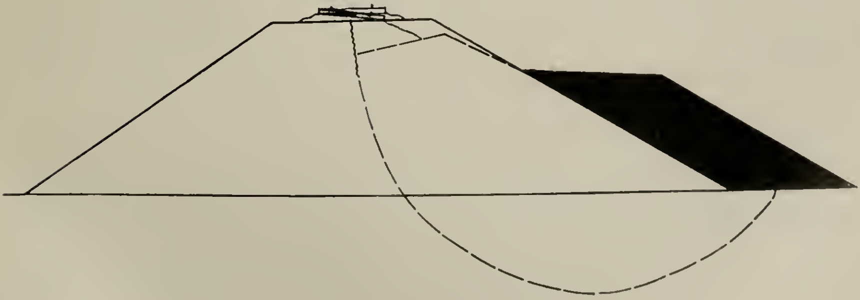


Fig. 25

New Vertical Lift Bridge Over Chicago's Calumet River

By R. F. BECK

Chief Engineer, Elgin, Joliet & Eastern Railway

I appreciate the opportunity of discussing with you some of our experiences with movable bridges.

This is about our old swingbridge, Bridge 710, over the Calumet River in South Chicago, Illinois, and its new offspring which was placed into operation just a few weeks ago.

Let's take a look at the old bridge. . . . Back in 1893 Congress authorized the construction of a swingbridge over the Calumet River which was completed in 1895. The channel depth at the time was 16 ft. It has now been dredged to the depth of 27 ft in the south draw. The old bridge cost 125,000 dollars compared to 7 million dollars for the new bridge. The engineering costs were only 47,000 dollars, compared to over 275,000 dollars for the new bridge. Perhaps more engineering should have been done, because by 1911, the west side of the center pier started settling, and the bridge could not be closed. Furthermore the bridge was not strong enough to carry the new 162-ton steam locomotives. These difficulties were corrected by adding timber foundation piles, concrete jacketing of the pier encased in sheet piling, and strengthening of the floor system. It looks pretty good for an 1895 facility. If only all of our other facilities in the area were as good.

Throughout the years, the bridge has been moved by various methods. It was first moved by a steam engine located in the bridge house. In 1915 electric motors were installed. The bridge has also been moved by air winches and by a method dating back to the Pharaohs of Egypt, manpower. A fifth method of movement, certainly not recommended, will be covered later.

The horizontal clearance in the south draw through which vessels navigate was only 82.5 ft, making it extremely vulnerable to damage. It's easy to see why the bridge and its protection have been struck over 50 times just since 1965. An approach span was destroyed by a vessel in 1944. In 1955 a Swedish vessel struck the bridge in a half opened position and almost knocked it into the river, causing us serious problems.

Let's talk about a recent fifth method of movement. On a balmy spring night just a few years ago, the tug Rhode Island was towing the vessel Jack Wirt upstream. Apparently the two captains were having some communication difficulties because one captain thought the Jack Wirt was going up the north draw but the other thought it was going up the south draw. This apparent lack of communication became most noticeable when the Jack Wirt hit the opened bridge head on, coming within a hair of completely knocking it off the center pier and into the river.

The wedges were dislodged, timber protective cribbing destroyed, one end diagonal bent, and the lateral bracing on the truss bent. All parts of the center pivot mechanism were practically wiped out, making the bridge completely inoperable.

Working with American Bridge Division we came up with a plan to expedite repairs by placing pontoons under each truss and floating the bridge to the river's edge. We could then go to work on the center pier. Before this could be done, however, the bridge had to be strengthened to prevent its collapse when it was raised above the center pier. Detailed calculations on stress reversal indicated that some pretty big girders were required for strengthening. These were moved out on the bridge and made an integral part of the structure. It was necessary to place and weld small girders to the main ones. In the meantime, two pontoons were constructed for the floating and raising operation. Prior to this operation, however, protective cribbing in the center of the river had to be removed to provide room for the pontoons. We finally had to resort to underwater demolition. Everyone, including the environmentalists, thought that the Calumet River was completely polluted. Not so. Dead fish appeared as a result of underwater demolition.

The water filled pontoons were floated underneath the bridge. The water was then pumped out, and the bridge slowly raised above the center pier. With the strengthened truss now resting on two pontoons, the structure was then carefully maneuvered to shore with the aid of tugs. We were thus able to start removing damaged machinery and start to rebuild the entire ring gear, spider, etc., on the center pier. As soon as this work was completed, the bridge was floated back to the center pier to be made operational. The trusses were so badly racked and twisted that we had difficulty in lining up the bridge with the track on both sides of the river. After working literally day and night for 19 days, 17 hours, and 15 minutes, the bridge was placed back in operation. You can now appreciate why I don't like moving the bridge in this fashion.

Enough of the old bridge; let's talk about the new one. After extensive public hearings over a period of many years, the old bridge was finally declared hazardous to navigation under the Truman–Hobbs Act. We had known for a long time, however, that it was really a hazard to the Chief Engineer. The official Order to Alter calling for a new bridge was received from Washington in March of 1969. Bids were opened December 15, 1971 and construction started on April 17, 1972. The new bridge was placed in operation just a few weeks ago although the old bridge has not yet been removed.

Our consulting engineers were Sverdrup & Parcel and Associates. The general contractor was J. M. Corbett Company. The towers and spans were fabricated and erected by American Bridge. The new single-track vertical lift bridge has a 242-ft span with 45-ft-long flanking tower spans. The old bridge underneath is dwarfed by the new one. The lift span provides 210 ft horizontal clearance for navigation purposes with a minimum vertical clearance of 125 ft above low water datum. The towers soar to about 180 ft with the machinery house approximately 200 ft above water.

The bridge is unique in some respects. From what we have been able to determine, it is the strongest railroad bridge ever constructed. It is designed to carry a series of fully loaded, 250-ton six-axle hot-metal ladle cars weighing close to one million pounds. AREA Cooper E 80 loading is now standard for new bridges but the actual design live load stresses for various individual structural members of this bridge exceed E 80 rating, running from E 110 to E 148. The dead load weight of the lift span is in excess of 600 tons.

Construction of the new bridge presented problems because it had to be located practically on top of the existing swing bridge which had to remain in operation. . . . No other location was possible because the track on the span had to tie into existing tracks which could not be relocated. High tension towers had to be relocated while at the same time maintaining electrical service to U. S. Steel's South Works to prevent a shutdown. Restrictive track layouts and sharp curvature were also mandatory because of the severe space limitations.

As all of you are aware, subsurface work seems to go painfully slow and little progress is apparent. The moving in of equipment, the driving and dewatering of cofferdams and attendant problems, the bridging required for heavy work equipment, and other related work finally comes to an end and caisson work begins.

The caissons are founded on cylindrical sockets cored into rock. The caissons are steel shells 30 inches in diameter, over 100 ft long, reinforced with structural steel core sections, and are concrete filled. There are six under each abutment and 10 under each pier. The design load on a single caisson under the maximum combination of loading is limited to 1,000 tons.

A unique method of installing the caisson steel shells was used. Using 42-inch guide casings, the contractor drilled oversize holes to approximately 10 ft above the rock, 100 ft below the river's surface, using conventional drilling equipment. The 30-inch caisson shells were then installed in these oversized holes and were twisted down through the overburden and into the rock. Rather than using the customary cutting shoe, the contractor attached carbide chips to the bottom of the caisson to permit cutting into the rock. Subsequently, industrial diamonds were substituted for the carbide chips because of their superior cutting and wearing qualities. The cutting edges of the caisson shells were drilled into the rock as much as 5 or 6 ft. At the lower elevation we ran into methane gas from a clay seam in the rock. This gas caused a small explosion and fire. As a result, steel core sections of increased size were set.

Forming and concrete work for the piers and abutments followed. Progress is always slow during this phase of construction.

The tower and lift span members, floor members, machinery sheaves, counterweight boxes and other structural elements were fabricated by shop welding thereby effecting a weight savings with resultant economy. All shop and field connections were made with highstrength bolts. Erection proceeded rapidly with no major problems. As far as we can ascertain, this is one of the first, if not the first, all-welded railroad through-truss bridges in the country.

The new span was erected on a barge a half mile upstream and began its trip at daybreak to the final site, passing under the 92nd Street bridge en route. Some very difficult maneuvering in a most restrictive area by three tugs was required to place the span in position for raising. After making the necessary guide adjustments, the counterweight near the top of the tower was released. With the aid of air-driven motors the span was slowly raised into the elevated position. . . . This entire operation took approximately 12 hours. The new bridge was then locked in the up position while the old bridge continued to swing underneath. This permitted all of the mechanical, electrical and signal interlocking to be installed. The control system utilizes modern solid-state electronic control elements, arranged for completely automatic control after initiation by the bridge operator. Electric interlockings in the operational controls insure proper sequencing of operations. Flexibility and reliability of operation are provided through an auxiliary motor-driven system, brake redundancy, and other critical control components. The time required to fully open the span is approximately three minutes. Approximately the same interval is required to close the span. Because of the balanced construction of the span and the close relationship to the weight of the counter balances, the new bridge requires only 25-hp electric motors in each tower to lift it. Should the larger motor fail or need repairs, backup electric motors of 5-hp each working through gear reducers will lift the bridge. The installation of elevators on both towers will prove to be a boon to maintenance forces we believe. Who knows, upon completion this area may become a tourist attraction.

Concrete Repair by Epoxy Injection

By B. J. KING
Bridge Engineer, Coast Lines
Atchison, Topeka & Santa Fe Railway

In this day of cybernetics, electronic data processing, linear induction engines, computerized classification yards, automatic car identification and larger, more automatic and more costly hardware of all types, it is difficult to arouse any excitement over the maintenance of a 70-year-old bridge. However, this subject is becoming a little-recognized but major problem in the railroad industry.

Railway bridges of any magnitude in the United States are generally composed of steel and concrete or masonry, all of which are susceptible to certain limits of loading and weathering. The average age of these structures is now approaching maturity of their expected life span when designed. Even in terms of today's materials, methods and criteria, one could certainly expect the need of maintenance and repairs, and most of us are aware of the minimal amount of attention our bridges receive.

These same structures are being called upon to carry continually heavier loads at faster speeds and greater frequency. Last year approximately 847 billion ton miles were carried by rail; an increase to over one trillion in 1980 and 1.6 trillion ton miles by 1990 is predicted. It does not take much foresight or engineering intuitiveness to see what the future could hold for the thousands of structures approaching the centurial age designed for 45,000- to 55,000-lb axle loads and carrying 4-axle cars with up to 315,000 lb gross weight.

Our engineering supervision must be awakened and management alerted to the impending situation. A concerted effort manually, mentally and monitarily must be made to alter our maintenance programs from attempts to hold a status quo position to aggressive, well directed efforts at giving added longevity to those structures that warrant it and replacing those that do not. Ambitious maintenance programs with increased inspection and supervision, applying innovative methods, materials and designs, are the keys to a realistic solution to the impending problem. The railroad industry can ill afford the costs or the track time required of an extensive replacement program, nor can it survive a series of major disasters.

The Santa Fe has taken its first steps in such a program by re-establishing paint gangs, replacing timber decking with composite-acting prestressed concrete, in-place timber preservative treatment program, marine pile protection program and an epoxy injection program. Three of these maintenance programs were originated by and are perhaps unique to the Santa Fe. The epoxy injection program which entails pumping epoxy-resin compounds under pressure into structural crack systems in concrete or masonry bridge members has gained a very solid and important position with us and I would like to talk of this today.

Epoxy resin can be defined as any molecule containing more than one epoxy group capable of being converted to a useful thermostat form. As early as 1909 it was known that olefins could be converted to epoxy groups. In 1927 there was a commercial attempt to prepare resins in the United States and again in Germany in the thirties. However, credit for the synthesis of the material first designated as epoxy resins, as we know them today, is shared by Dr. Pierre Castan of Switzerland and Dr. S. O. Greenlee of the United States. Some of their more important early work took place from 1936 to 1939 to set the stage for commercial utilization of epoxy resins.

In the past decade probably no new materials have captured the interest of the concrete construction industry as have the epoxy-resin compounds. These compounds combine rapid curing, good adhesion, toughness, good strength properties and superior chemical resistance to most acids, alkalis and solvents in such manner as to make them ideal for certain phases of concrete construction, repair and maintenance. This recent interest has resulted in phenomenal progress in the commercial and technical development of this structural adhesive.

Historically, there has been an increasing number of available methods of concrete repair or restoration which range from remove and replace through reinforced concrete encasement, dry pack, preplaced aggregate concrete, pneumatically applied grout and grout intrusion. However, there has been no readily applicable method to heal concrete which is deteriorating or structurally failing by systems of surface or structural cracks. Generally it appears our practice with such crack systems is inspect and record and then undertake a game of brinkmanship in the determination of when the condition can no longer be carried. That portion of the structure must then be renewed.

Awareness of some of the accomplishments in the concrete construction industry with epoxy-resin compounds prompted the Santa Fe to authorize a small expenditure to test the ability of an epoxy compound to achieve its adhesive qualities in the dirt- and grease-laden structural cracks in our aged and deteriorating bridge structures. In 1967 the structural cracks in a pier were flushed and pressure injected with Concresive 1050 adhesive. Concrete cores were then taken and tested for compression, shear and bonding strength of the injected epoxy. The results were excellent. However, to satisfy some questions that still remained, we made comparative tests with grout intrusion and, unsurprisingly, they turned out rather poor. Due to the comparative tests, the use of epoxy injection in our maintenance program was delayed one year, but in 1969 we got underway and have had a contract for this service annually since that time.

Epoxy injection is a wonderful tool for the engineer but it should not be misconstrued as a cure-all. If all of the loose material cannot be removed from the cracks, if grease or chemicals which cannot be economically cleaned out are present, if the concrete is not sound, if the cracks are working, epoxy injection will be ineffective. It should be remembered that it is far better, and much easier, to prevent concrete cracking and deterioration than to effectively repair it.

Our procedure in the use of the epoxy injection method of repair is composed of five basic steps. Visual inspection of the candidate is first, to determine if the crack system appears healable; fairly sound underlying concrete and non-working cracks are requisite. At this time it is decided which cracks are to be injected and if any special handling is necessary, such as stitching a crack with reinforcing bar, placing aggregate in very large cracks to cut down on the amount of epoxy used, surface patching and surface sealing.

When the injection crew begins a job, the second step, preliminary coring, is undertaken. These cores are to substantiate our visual decisions. They also reveal the depth of cracks, how badly and with what the cracks are contaminated. This determines the method of flushing to use and if special flushing techniques or materials are needed.

At this point we are ready for the injection steps, which entail cleaning the concrete surface by sand blasting for sealing the cracks or the complete surface, flushing the crack systems, placing pumping ports, sealing the cracks and pressure injecting the epoxy compound.

After the injection has been completed the fourth step, record coring, is undertaken. These cores are to assure that satisfactory penetration and strength characteristics were achieved, or if reflushing and injection is necessary in some areas.

The fifth and final step is the surface treatment, which is optional. Dampproofing, epoxy, an esthetic coating or nothing are the options we are using currently.

The state of the art of epoxy injection is still in its infancy and the combination of conditions that can be encountered at a remedial candidate seems to be infinite. Therefore, the details of the method of the basic procedural steps and the materials utilized are still extremely variable.

A Planning, Scheduling and Reporting System for MW&S Basic Force

By R. G. BROHAUGH[1] and D. D. THOMAS[2]

REMARKS BY MR. BROHAUGH

We have developed a system for planning the daily activities of the basic force on the Burlington Northern and have named the program PS&R, the letters signifying "Planning, Scheduling and Reporting." Our purpose here today is to describe the system to you and tell you something of why we do it and how the system works.

The Burlington Northern was formed in early 1970 by the merger of the Northern Pacific, the Great Northern, the Chicago, Burlington & Quincy, and the Spokane, Portland & Seattle Railways. The maintenance forces of the four companies were smoothly and successfully melded into an effective work force with new standards as to work procedures and materials.

A merger such as ours presents a great opportunity to select from the best ideas and standards from each of the component companies for use on the new system. Each railway brought lengthy experience in the way of knowledgeable people, sound work practices and proven hardware and appliances. From these valuable resources, we selected the best for use on Burlington Northern.

Another area which we considered was the maintenance-of-way organization and the reporting relationships between the 15 Divisions and the 6 Regions. Also, the relationship of the Regions to Headquarters. Planning procedures for larger projects involving seasonal extra gangs were established primarily with Headquarters leadership because of the need to allocate and supply materials on a system basis, such as rail and ties. Also, certain machinery had to be scheduled for use on several Regions in order to obtain full utilization.

The planning and scheduling of this out-of-face type work was done thoroughly and completely with productivity and cost goals being set for each project. Each programmed project is monitored to assure accomplishment of the goals established. This is an important effort because of the need to complete the work in a timely and economical manner and to properly utilize the 3500 man seasonal force which is employed during the summer months. We believe we have this type of work under meaningful and effective control.

---

[1] Chief Engineer Maintenance, Burlington Northern, Inc.
[2] Assistant Chief Engineer, Special Projects, Burlington Northern, Inc.

About two years ago, however, in examining our total maintenance-of-way forces, we decided it was essential that we do something about increasing productivity of our 6600-man basic force—the force that works year around in the section crews, the bridge crews, the welding crews, pipefitters, electricians, etc. Although much of this work is routine, it can be planned and scheduled, and improved utilization of manpower obtained.

The maintenance responsibilities of basic force have undergone considerable change over the years. Much of this change is relatively recent, coming with mechanization of maintenance operations. Most of the heavy work is performed by specially equipped extra gangs which renew ties on an 8- to 10-year cycle, lay the rail on a cycle dependent upon tonnage, and reballast and surface the track, also on periodic cycles.

This procedure relieves the section crews from doing out-of-face maintenance, but their presence is necessary to change a rail, spot up a joint, renew some joint ties, repair road crossings, fight right-of-way fires, repair washouts and many other necessary jobs. The crews must be distributed properly to provide this "caretaker" type capability and they must be of proper size to perform these functions adequately.

There are four major functions performed by the basic force:

1. Perform all maintenance work and all improvement projects within their capability to perform as to manpower and equipment.
2. Provide assistance as necessary to other departments of the railway.
3. Perform routine and special inspections of track and structures as may be required.
4. Act in case of unforeseen event or emergency to repair or protect railway facilities.

Of these four primary responsibilities, items 1, 2 and 3 can be largely planned and scheduled, but not completely. Item 4 cannot be planned, and any planning system must be flexible enough to provide for interruptions to the plan for emergencies or other unforeseen demands of higher priority. However, with careful consideration, a plan and schedule of man-hour requirements and work projects can be prepared for a major portion of the man-hours available. We started out scheduling 75% of the total man-hours and have found this to be the minimum necessary. In many cases, the plan should cover 100% of the crew's time, such as would be the situation with a joint welding crew. On an average, we have found for our system that about 85% of the man-hours can be planned—which is a figure that surprised all of us.

From a practical point of view, there are two ways of increasing the productivity of basic force.

1. Perform the same amount of work with a reduced force.
2. Perform more work with the same force.

It is not a simple matter to determine exactly which of these conditions to apply, and very likely in many cases a combination should be considered. However, if maintenance forces are over-manned, the first procedure may be employed—reduce force and obtain the same work output. If maintenance forces are not over-manned and are at a minimum essential level, then ways must be conceived to produce more work from that minimum force, thus increasing productivity. Improved planning is a device which eliminates wasted labor and assists in accomplishing more work from a minimum force. We decided to seek our answers along these lines by designing a planning system for use by the basic force and in addition to conduct an extensive examination of all manpower assigned to the basic force to be certain that it was not too large or too small to meet requirements, and that the crew was headquartered at the proper location with an assigned territory consistent with all local conditions.

Actually, productivity means getting your money's worth from the labor applied to the essential tasks. In the case of the basic track and bridge & building crews, it is sometimes very difficult to determine whether you are getting your money's worth from a crew unless you know exactly what is expected of the crew when they are assigned to an item of work. The only person who really knows what a crew is to do, or how they should do it, or how long it should take, and when they should do it, is the first line supervisor for that particular crew. For a section crew we are talking about the district roadmaster or the track supervisor, or the supervisor of roadway maintenance, or by whatever title he is known. I'm sure you recognize who I mean by first line supervisor, as regards other crews in basic force. It is this supervisor who must set the work priorities, the productivity goals as to the man-hours required for each job and see that quality workmanship is obtained. In any system set up for increasing the productivity of basic force, the first line supervisor is the important officer on whom the system depends. It is he who must decide whether labor is assigned to mow the grass on the depot lawn or to spot up some low joints on a curve. He is the prime mover, and not only must he be the primary planner and scheduler, he must be the one to whom the crew reports results and accomplishments for review and evaluation. All maintenance officers must participate in the planning, but their participation should be channeled through the first line supervisor.

Another problem to be addressed is that of determining the proper time required to perform a particular job. Average times can be established for any of the items of work performed in order to set the basic units of time for measuring productivity. Such average times can be developed by observation of properly performed work and norms established. However, in using the average times it must be realized that wide variations will occur because no two maintenance jobs are really alike. The repair of two different farm crossings may require vastly differing work times dependent upon tie condition, track surface, joint condition, etc. Adjustment of rail anchors at one location could require twice as many man-hours as at another location because of the type of rail anchor, the fullness of the cribs, the condition of the ballast and other factors. We feel that the most meaningful man-hour allowance for each item of work planned should be established on an individual basis by the first line supervisor. To simplify the matter for practical purposes, the time allotted should include allowance for travel time and train interference.

Another factor to consider is the need for a measure or index as to productivity. This is a difficult area, but if the first line supervisor prepares a good plan and schedule for his crews and the crews perform well in accomplishing the jobs, good productivity is obtained. Measuring plan against performance gives an index of productivity, and, by dividing planned man-hours by actual man-hours utilized in performance of the planned work, a ratio is obtained which is directly related to productivity.

In all of these procedures, the importance of the first line supervisor cannot be over-emphasized. This man is in a key position and considerable skill and knowledge are required to successfully manage and perform the required responsibilities. To assist in these matters, we feel a special training program is ncessary and we are preparing to start a supervisor training program next year. Also, the foreman, assistant foreman and track inspectors are important supervisors in a successful maintenance program and, here again, training is required. As a matter of fact, we have started a foreman training program and will train about 200 men a year in a combination of classroom and field assignments for the purpose of expanding their knowledge of maintenance practices and procedures. Training of supervisors and foremen is extremely important and we intend to devote considerable time and effort to such an endeavor.

Up to this point, I have discussed in rather random fashion our deliberations on the problem of improving performance by the basic force, a problem which is complex and difficult to approach. However, we decided that we would attack the situation in three major categories, with the following actions:

1. Devise and implement a Planning, Scheduling and Reporting system including index as to productivity.
2. Conduct an intensive study of maintenance forces to properly size and locate the crews.
3. Develop a maintenance supervisors' training program to improve their quality and effectiveness.

Mr. Thomas, who will follow me, will describe in greater detail the steps we have taken in these three major areas. However, as to the Planning, Scheduling and Reporting system, we developed a format for planning and reporting and labeled the system PS&R. In designing the PS&R system, we exerted considerable effort in making all routines simple, yet making certain that the basic objectives of increased productivity and efficiency were obtained.

The study of basic force for the determination of proper manpower and distribution was conducted by knowledgeable and experienced maintenance officers whose capabilities had been proven by successful performance of a wide range of responsibilities in various engineering and maintenance positions. Two such men were assigned to a Study Team and, as such, toured the entire system by highway–railway vehicle examining conditions, interviewing all maintenance people and listening to everybody who had factual information to present. From this inspection, joint recommendations were prepared involving changes in manpower—both upward and downward, and shifts in headquarters and alterations in territories. All responsible operating and maintenance officers participated and the result has been the establishment of the proper basic force for our railway. I am proud to say that our people cooperated in this effort, which required considerable self-discipline and restraint in viewing local conditions and requirements within the framework of our total corporate objectives.

Our training program is just getting underway, with the first class of 20 foremen, assistant foremen and track inspectors being assembled in St. Cloud, Minnesota, on Monday, November 4, 1974. Here again, we selected very carefully the men to organize and conduct the training sessions. We have two men working on this assignment who are not school teachers, but who have extensive engineering and maintenance backgrounds. The 20 men who have just entered the training program will be given 5 weeks of classroom sessions, consisting of one week per month over a 5-month period. In between classroom sessions, they will be assigned to at least 2 weeks of special field assignments, specifically selected to augment their experience. The remaining free period between classes will be spent on their regular job. We look for good and valuable results from this training effort.

There is one more important feature of our program which should be mentioned. As we studied our traditional methods of planning and giving orders to the basic force, we could find no particular fault with the methods used, for the most part, and we desired only to improve, formalize and set a routine to the process in order to improve communications and the exchange of information between the first line supervisor and his crew. We wanted to create a regular, written routine for the planning which formerly was done verbally at intermittent intervals. We wanted a written report to be returned to the planner so he would know precisely the progress of work on his plan. We wanted both the planner and the crew to be able to consider and evaluate how well they did in accomplishing planned work so they would be fully informed as to their efficiency and productivity. As a result, we generate very little in the way of management reports from the system. The PS&R program is sampled in random fashion by System, Region and Division maintenance officials on trips and periodic inquiries, but we have made no massive commitment to the generation of voluminous reports and paperwork in feeding the basic documents involved up through the organization. We feel such a procedure is unnecessary and would divert attention from the primary objectives of PS&R program, which is to increase productivity of basic force.

This has been a rather general presentation of our efforts to improve our performance and to gain greater utilization and productivity from our basic force in track and B&B, and now to describe in somewhat greater detail our PS&R system and our manpower evaluation activities, I would like to introduce D. D. Thomas, assistant chief engineer special projects of Burlington Northern.

REMARKS BY MR. THOMAS

The Burlington Northern in years past has made studies of maintenance-of-way forces, but not as carefully and as extensively necessary to determine where and how adjustments in manpower could be made and to provide a system to increase productivity in the basic maintenance forces.

We have virtually completed a comprehensive study of all basic maintenance forces and a method has been developed for planning, scheduling and reporting for the basic maintenance forces.

The system proposed, is labeled Maintenance—PS&R—Plan, Schedule, and Report System of Basic Maintenance. The system consists of a study of track and B&B crews with two main goals.

First, establishment of the PS&R system to provide an organized format of planning, scheduling, and reporting.

Second, an intensive study of basic forces to properly size and locate crews.

We initiate the PS&R Program by Division with an initial PS&R meeting with Regional maintenance officers. The initial Regional meeting is a general presentation of the PS&R Program and a brief outline of how the program will be implemented on the Divisions under each Region.

The Division Instruction Seminar concerning the actual implementation of the PS&R system of basic maintenance is an essential meeting. At this meeting we go into every detail of the PS&R system of basic maintenance.

The study team then goes into the field for an intensive study of field basic forces. These basic crews do not consist of tie gangs, steel gangs or any type gang programmed on a yearly basis or extra type gang doing system programmed work. We are looking into basic force type gangs working the year around, similar to section gangs, permanent type district maintenance gangs, and B&B gangs. The study required the riding of all Divisions on a highway–railway vehicle and walking through most major yards and terminals.

The study team then writes up a complete preliminary report of its findings and recommendations by Division. This is an independent report similar to a consultant type report except that the study is made by inhouse railroad personnel with maintenance and engineering backgrounds. This preliminary report is presented to the PS&R Steering Committee at the end of each Division study.

The Steering Committee analyzes the preliminary report and, along with the study team, makes its final recommendations in a final PS&R Division Report. Upon approval of the final report, the report is then implemented on the Division.

This process is repeated for each Division on the system for which we have 15 Divisions. At the present time we are now working on the last Division. The Program has taken 1½ years to implement.

In our field studies to size and locate crews, there are several factors that we use. First of all we have our own built-in targets that come with years of experience in the field. We rate by comparing work loads observed with our own concept of normal work loads. Consistency of ratings is most important. We can assess the work loads in terms of group judgements, work sampling, work elements, or representative studies of variable elements. We have to justify our judgements by statistical, trained judgement and accepted judgements. We also have given standards to comply with. Force allotment by money, company policies, or procedures, and of course directives from the chief executive officers.

A very tactful approach has to be used in making adjustments of basic forces. No maintenance supervisor likes to be told how to reduce his forces or how to size and relocate his crews.

At this point we try to involve the first line supervisors to incorporate their ideas with ours for adjustments in Basic Forces or relocating crews. This might involve local problems that only the first line supervisors have knowledge of. We depend on what the first line supervisor shows us in work loads for each crew. In some areas, especially in heavy terminal areas, the real work loads are hidden to the observer, therefore we are dependent upon the first line supervisor to show us these work load areas or troubled spots that require special attention.

Before the study team goes into a Division we gather every statistic available concerning this Division. We know the present basic force count by crews, districts and division. We know actual and equated miles by sections and divisions; also equated and actual miles per man. We know gross ton miles by sections of track, or subdivisions. Section limits by mileposts are known. Also roadmaster's districts are laid out on maps with all the sections colored in and marked for locations. We prestudy the condensed track profiles to know grades and curvatures. And one of the most difficult statistics to come by is the manpower apportionment tabulations.

This tabulation is developed by going through the time distribution charges for each section and B&B gang and how they charged their working time for one year previous to our study. This tabulation is then converted to ICC account numbers in terms of manpower assignments by gangs as to how they proportioned their men during the previous year. This gives us an analysis of each crew's work for the entire year. In other words, we have a thorough understanding, statistically, how the Division is functioning before we ever go into the field to study work loads.

Work loads have a very tangible meaning in our study. Otherwise we might just as well stay in the office and adjust crew sizing and locations by using a statistical analysis.

A few examples that might constitute work loads which are not picked up in our statistical analysis are as follows:

1. Travel time involved either by truck on the highway or motor car on the track.
2. Accessibility to the right-of-way or tracks between given section limits.
3. Subgrade problems such as sink holes or soft spots.
4. Location of the track structures such as in rock canyons where slides or washouts may occur, or sand blows could cover tracks.
5. Geographical locations—severe winters or extremely hot summers.
6. The track structure itself concerning type of ballast, tie condition and type of rail.
7. Section limits could be poorly located in reference to crews headquarters.
8. Vegetation and brush control along right-of-way.

All these items affect the working conditions, along with any special local condition that might greatly affect the work loads.

Here again these work loads are all discussed with the local maintenance supervisors as to how they affect the working limits and sizing of crews.

This is one part of our program. As stated earlier we have a two-part program. The other part is the PS&R System (Plan, Schedule and Report) that will be used by basic maintenance forces to provide a system to increase productivity and efficiency among our basic crews.

All factors have been covered in establishing efficient production gangs such as working on relays, ballast, ties and surfacing. Careful planning, scheduling and reporting of this work has improved productivity and gives production costs per man-hour, and unit costs that are being used to measure and increase productivity.

The PS&R system (Plan-Schedule-Report) that is in use for basic forces addresses itself to a different problem because of the nature of the work performed and because of the primary purpose and function of this group. The work for these basic force crews cannot be planned and scheduled a year in advance as with the production gangs; therefore, the PS&R System is based on a semi-monthly plan, schedule and report system. This system is primarily a tool to be used between the first line supervisor and his crews.

In years past a maintenance-of-way supervisor did not prepare written plans or programs for short-term scheduling of weeks, or months, for his basic forces. He was on the line-ups in the morning and verbally planned the day's work with his foreman. It was hard for him to get feed-back as to how well the job was progressing, or whether the job was completed in a productive and efficient manner. He did not know how much time was taken to complete the job, or whether it was accomplished in an efficient manner in terms of hours used to complete the job. Basically, the PS&R system has been designed so that the first line supervisor can better manage these questions in a productive way: to set up his programs or items of planned work on a priority basis; to properly schedule his planned hours for each job so that the crews have less not-planned work; to utilize his basic forces for greater productivity. In short, the first line supervisor is functioning like a manager; he will utilize the PS&R system to increase productivity and efficiency without sacrificing quality of work.

The PS&R system is a simple but complete system using basically one form for planning, scheduling and reporting. The form is designed so that the planning section is on the left side under items and description of work. The schedule portion is the center section where the planned hours are scheduled by the day for a semi-monthly period. The report part of the form is the actual hours recorded with a summation of these hours in totals where they can be computed into percent hours used on planned work and percent efficiency.

The plan is the originating function of the PS&R system. Scheduling is dependent on the planned work items. In the initial planning stage any officer, supervisor, foreman or machine operator might be involved in the plan preparation. This can be by a direct order from System, Region or Division officers, to the supervising planner; or by letter, message and phone calls from various officers and supervisors. The foreman or machine operator will also be in direct communication with his supervisor in the initial stage of planning.

The first line supervisor will incorporate all these suggested planned items of work with his own into a priority listing of planned work items for each crew on his PS&R form. The planned man-hours will be scheduled within the semi-monthly period.

We plan for a minimum of 75% of the crew man-hours, allowing 25% for unplanned duties which arise on a day-to-day basis. A schedule must provide some consideration for the fact that planned work may be interrupted for emergencies or other demands of higher priority. However, with careful consideration, a plan and schedule of man-hour requirements and work projects can be prepared on a semi-monthly basis for a major portion of the man-hours available. We have found in some instances that planning 100% of the crews' time is much more advantageous, and actually easier for the planning supervisor. Presently our system average is 85% of the crews' time on planned work.

The validity of the PS&R system will depend upon careful preparation of the plan and proper scheduling of hours so that a realistic program can be accomplished. The system has to be monitored from all concerned.

The PS&R system lets the planning supervisor set his own goals or target time to complete a unit of work. We believe this method of targeting or setting goals is more realistic when dealing with basic crews. Basic crews are usually not production-oriented type crews that can be computed on a daily basis for repetitious type units of work. Basic crews do daily type chore work that varies by the day or even hours. The conditions of work vary greatly from section to section, therefore one section doing the same unit of work as another section may differ completely as to the targeted time to accomplish this unit of work due to local conditions.

As of to date, we have not had too many problems with our system. Most supervisors do plan or at least try to plan on a daily basis. This was traditionally accomplished by word of mouth. The PS&R system provides a system for the first line supervisor to plan and schedule his basic crews in an organized format.

The measure of plan against actual performance of plan is a meaningful index of productivity. The index will depend upon the supervisor's careful preparation of the work schedules in priority order for his crews and the productivity will be increased because of advance planning and budgeting of man-hours.

In conclusion: this system is designed to provide the first line supervisor with the techniques to Plan, Control and Report for the prime purpose of effectively increasing productivity under varying working conditions. The PS&R system is operating successfully and we are accomplishing the goals that we set forth.

DIRECTORY
CONSULTING ENGINEERS

FRANK R. WOOLFORD

Engineering Consultant—Railroads

24 Josepha Ave.
San Francisco, Ca. 94132
(415) 587-1569

246 Seadrift Rd.
Stinson Beach, Ca. 94970
(415) 868-1555

WN

Westenhoff & Novick, Inc.

Consulting Engineers

Civil—Mechanical—Electrical

Fixed & Movable Bridges
Soils, Foundations, Buildings
Structural & Underwater Investigations
Planning, Feasibility, Design, Inspection

222 W. Adams St., Chicago, Ill. 60606

New York Washington Panama

HAZELET & ERDAL

Consulting Engineers

Design Investigations Reports
Fixed and Movable Bridges

150 So. Wacker Dr., Chicago, Ill. 60606
Louisville Cincinnati Washington

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF

Feasibility studies and design services for

Terminals
Parking
Tunnels
Utilities
Structures

Bus and rail transit
Regional and urban planning
Soils and foundations
Environmental impact studies

Offices in 29 cities 816 474-4900
1805 Grand Ave., Kansas City, Mo. 64108

MODJESKI AND MASTERS

Consulting Engineers

Design, Inspection of Construction & Inspection of Physical Condition of Fixed & Movable Railroad Bridges

P.O. Box 2345, Harrisburg, Pa. 17105
1055 St. Charles Ave., New Orleans, La.

CLARK, DIETZ AND ASSOCIATES—ENGINEERS, INC.

Consulting Engineers

Bridges Structures, Foundations, Industrial Wastes and Railroad Relocation

211 No. Race St., Urbana, Ill.

Sanford, Fla. Memphis, Tenn.
Jackson, Miss. St. Louis, Mo.
Chicago, Ill.

Engineers

Designers Planners

PARSONS BRINCKERHOFF QUADE DOUGLAS

Route Location, Shop Facilities, Container/Bulk Cargo, Handling Utilities, Bridges, Tunnels, Evaluations, Appraisals, Supervision

ONE PENN PLAZA, NEW YORK, NY 10001

Boston • Denver • Honolulu
San Francisco • Trenton

HARDESTY & HANOVER

Consulting Engineers

MASS TRANSPORTATION

Highways • Railways
Bridges—Fixed and Movable
Design • Resident Inspection
Studies • Appraisals

101 Park Ave., New York, N. Y. 10017

THOMAS K. DYER, INC.

Consulting Engineers

Railroads—Transit Systems
Track, Signals, Structures

Investigations and Feasibility Reports
Planning, Design, Contract Documents

1762 Massachusetts Avenue
Lexington, Mass. 02173

DCO The De Leuw, Cather Organization

CONSULTING ENGINEERS

165 W. WACKER DRIVE • CHICAGO 60601

SUBWAYS • RAILROADS • PUBLIC TRANSIT
TRAFFIC • PARKING • HIGHWAYS
BRIDGES • PORT DEVELOPMENT • AIRPORTS
COMMUNITY PLANNING • URBAN RENEWAL
MUNICIPAL WORKS • INDUSTRIAL BUILDINGS
ENVIRONMENTAL SCIENCE AND ENGINEERING

ATLANTA • BOSTON • BUFFALO • NEWARK • NEW YORK
OKLAHOMA CITY • PHILADELPHIA • SAN FRANCISCO • SEATTLE
WASHINGTON, D.C. • BANGKOK • BEIRUT • SYDNEY

IECO

RAILROAD
DESIGN & ELECTRIFICATION

Planning • Design
Construction Management

INTERNATIONAL ENGINEERING COMPANY, INC.

220 MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94104

RILEY, PARK, HAYDEN & ASSOCIATES, INC.

Consulting Engineers

Survey Services, Photogrammetry, General Civil, Bridges, Railroads & Industrial Park Design.

136 Marietta St., N. W.
Atlanta, Georgia 30303
(404) 577–5600

R.W. BOOKER
& ASSOCIATES, INC.

ENGINEERS ARCHITECTS PLANNERS

1139 OLIVE ST. ST. LOUIS, MISSOURI 63101
LEXINGTON, KENTUCKY FORT WORTH, TEXAS

PORTER AND RIPA
ASSOCIATES, INC.

ENGINEERING · PLANNING · ARCHITECTURE

Design · Inspections · Reports
Planning · Structures
Environmental Studies

200 Madison Avenue, Morristown, New Jersey 07960

SVERDRUP & PARCEL AND ASSOCIATES, INC.
800 No. Twelfth Blvd. St. Louis, Mo. 63101

- *DESIGN*
- *PLANNING*
- *CONSTRUCTION MANAGEMENT*

Boston, Charleston, Gainesville, Jacksonville,
Nashville, New York, Phoenix,
San Francisco, Seattle, Washington, D.C.

CONSULTING ENGINEERS

SOROS ASSOCIATES

Consulting Engineers

Transfer Terminals & Ports For Dry Bulks,
Liquids & Containers—Waterfront Structures
Materials Handling Systems

575 Lexington Ave.
New York, N. Y. 10022
(212) 421–0400

Rio de Janeiro Santiago, Chile
Sydney, Australia

R. G. "SLIM" SIMMONS

Railroad Consultant

3009 George St.	30 Jackson St.
Franklin Park, Ill. 60131	Denver, Colo. 80206
(312) 678–7321	(303) 321–0902

A. J. HENDRY, INC.
CONSULTING ENGINEERS

SIGNALS • COMMUNICATIONS • AUTOMATION • ELECTRIFICATION
RAILROADS • RAIL TRANSIT

SUITE 810 OSBORN BUILDING
ST. PAUL, MINNESOTA 55102
(612) 222 2787

SPAULDING ENGINEERING CO.

CONSULTING ENGINEERS
MEMBER
AMERICAN CONSULTING ENGINEERS COUNCIL

1821 UNIVERSITY AVENUE
ST. PAUL, MINNESOTA 55104
PHONE 612/644-5676

TURNER ENGINEERING COMPANY

(SAWYER–PIEPMEIER)

RAILROAD ENGINEERING

306 GAY ST.
NASHVILLE, TENNESSEE 37201
615-244-2144
ALBANY, NY 518-456-1994

GOOD TRACK GOOD SERVICE

COAST TO COAST...

Let Speno show you the way to get significantly more ton miles of service from your rails. Send for FREE Booklets on Speno Ballast Cleaning and Speno Rail Grinding.

Ballast Cleaning • Rail Grinding

"Just Ask the Railroads That Use Our Services"

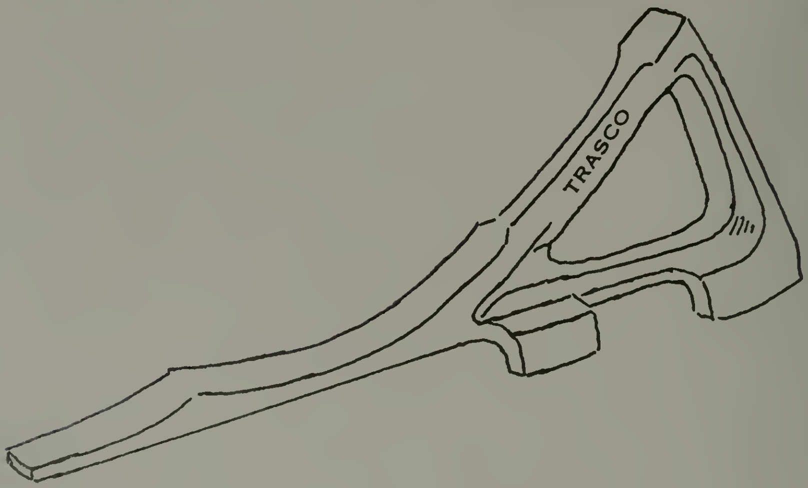
Frank Speno Railroad Ballast Cleaning Company, Inc.
306 North Cayuga St., Ithaca, New York 14850
Clark St., Box 219 East Syracuse, New York 13057

Speno International, S. A.
22 Parc Chateau Banquet, Geneva, Switzerland
(For Rail Grinding Outside the North American Continent)

MEMBER RPI

IEC-Holden Ltd.
8180 Côte de Liesse Road.,
Montreal, 376 P. Q., Canada

TRASCO Track Skates



Preferred by skatemen
Light
Tough
Balanced hand hold
No curl tongue

**TRACK SPECIALTIES
COMPANY**
Box 729 Westport, Conn.

American Railway Engineering Association—Bulletin

Bulletin 653
Proceedings Vol. 76*

June–July 1975

TECHNICAL CONFERENCE REPORT ISSUE

CONTENTS

President's Address ---------- 459
Special Features ---------- 463
Installation of Officers ---------- 645
AAR Engineering Division Session ---------- 649
Report of Executive Director ---------- 691
Report of Treasurer ---------- 703
AREA Constitution ---------- 709
Directory—Consulting Engineers ---------- 729

RECEIVED
AUG 27 1975
E. STALLMEYER

* Proceedings Volume 76 (1975) will consist of AREA Bulletins 649, September–October 1974; 650, November–December 1974; 651, January–February 1975; and 653, June–July 1975 (Technical Conference Report issue). Blue-covered Bulletin 652, April–May 1975 (the Directory issue), is not a part of the Annual Proceedings of the Association.

BOARD OF DIRECTION
1975–1976

President

J. T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, 500 Water St., Jacksonville, FL 32202

Vice Presidents

John Fox, Assistant Chief Engineer, Canadian Pacific Rail, Windsor Station, Montreal, PQ H3C 3E4

B. J. Worley, Vice President—Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Union Station, Room 898, Chicago, IL 60606

Past Presidents

D. V. Sartore, Chief Engineer—Design, Burlington Northern, Inc., 176 E. 5th St., St. Paul, MN 55101

R. F. Bush, Chief Engineer, Erie Lackawanna Railway, Midland Bldg., Cleveland, OH 44115

Directors

R. W. Pember, Chief Engineer—Design and Construction, Louisville & Nashville Railroad, P. O. Box 1198, Louisville, KY 40201

E. Q. Johnson, Senior Assistant Chief Engineer, Chessie System, P. O. Box 1800, Huntington, WV 25718

W. E. Fuhr, Assistant Chief Engineer—Staff, Chicago, Milwaukee, St. Paul & Pacific Railroad, Union Station, Room 898, Chicago, IL 60606

B. E. Pearson, Chief Engineer, Soo Line Railroad, Soo Line Bldg., Room 1520, Minneapolis, MN 55440

P. L. Montgomery, Manager Engineering Systems, Norfolk & Western Railway, 8 N. Jefferson St., Roanoke, VA 24042

E. C. Honath, Assistant General Manager Engineering, Atchison, Topeka & Santa Fe Railway, 900 Polk St., Amarillo, TX 79171

Mike Rougas, Chief Engineer, Bessemer & Lake Erie Railroad, P. O. Box 471, Greenville, PA 16125

J. W. DeValle, Chief Engineer Bridges, Southern Railway System, 99 Spring St., S. W., Atlanta, GA 30303

R. L. Gray, Chief Engineer, Canadian National Railways, P. O. Box 8100, Montreal, PQ H3C 3N4

E. H. Waring, Chief Engineer, Denver & Rio Grande Western Railroad, P. O. Box 5482, Denver, CO 80217

Wm. Glavin, General Manager, Grand Trunk Western Railroad, 131 W. Lafayette Blvd., Detroit, MI 48226

G. H. Maxwell, System Engineer of Track, Union Pacific Railroad, 1416 Dodge St., Omaha, NE 68179

Treasurer

A. B. Hillman, Jr., Chief Engineer, Belt Railway of Chicago, 6900 S. Central Ave., Chicago, IL 60638

Executive Director

Earl W. Hodgkins, 59 E. Van Buren St., Chicago, IL 60605

Assistant to Executive Director

N. V. Engman, 59 E. Van Buren St., Chicago, IL 60605

Administrative Assistant

D. F. Fredley, 59 E. Van Buren St., Chicago, IL 60605

Published by the American Railway Engineering Association, Bi-Monthly, January–February, April–May, June–July, September–October and November–December, at
59 East Van Buren Street, Chicago, Ill. 60605

Second class postage at Chicago, Ill., and at additional mailing offices.
Subscription $15 per annum

Copyright © 1975
American Railway Engineering Association
All rights reserved.

No part of this publication may be reproduced, stored in an information or data retrieval system, or transmitted, in any form, or by any means—electronic, mechanical, photocopying, recording, or otherwise—without the prior written permission of the publisher.

PROCEEDINGS

SEVENTY-FOURTH TECHNICAL CONFERENCE

American Railway Engineering Association

March 24–26, 1975

PALMER HOUSE, CHICAGO

VOLUME 76

AMERICAN RAILWAY ENGINEERING ASSOCIATION
59 East Van Buren Street
Chicago, Illinois 60605

OFFICERS, 1974–1975

R. F. Bush
President
Chf. Engr., E.L. Ry.

J. T. Ward
Sr. Vice President
Sr. Asst. Chf. Engr.
S.C.L. RR.

W. J. Jones
Jr. Vice President
Engr. M.W.&S., Sys.
S.P.T. Co.

R. M. Brown
Past President
Chief Engr.
U. P. RR.

D. V. Sartore
Past President
Chf. Engr. Design
B. N., Inc.

A. B. Hillman, Jr.
Treasurer

Chief Engr.
Belt Ry. of Chicago

Earl W. Hodgkins
Executive Director and Secretary
AREA

DIRECTORS, 1974–1975

B. G. Anderson
1972–75
Asst. Vice Pres.-
Engrg. B. N. Inc.

John Fox
1972–75
Asst. Chf. Engr.
C. P. Ltd.

C. E. Weller
1972–75
Asst. Vice Pres.-Engrg.
C.R.I. & P. R.R.

B. J. Gordon
1972–75
Chf. Engrg. Off.
P.C.T. Co.

R. W. Pember
1973–76
Chf. Engr.-
Des. & Const.
L. & N. RR.

E. Q. Johnson
1973–76
Sr. Asst. Chf. Engr.
Chessie Sys.

W. E. Fuhr
1973–76
Asst. Chf. Engr.-Staff
C. M. St. P. & P. RR.

B. E. Pearson
1973–76
Chief Engr.
Soo Line RR.

P. L. Montgomery
1974–77
Mgr. Engrg. Sys.
N.&W. Ry.

E. C. Honath
1974–77
Asst. Gen. Mgr. Engrg.
A. T. & S. F. Ry.

Mike Rougas
1974–77
Chief Engr.
B.& L. E. RR.

J. W. De Valle
1974–77
Chf. Engr. Bridges
Sou. Ry. Sys.

CONTENTS

Page
Officers, 1974–1975 ---------- 448

Directors, 1974–1975 ---------- 449

Technical Conference Program ---------- 451

Nominating Committee and Tellers Committee, 1975 Election ---------- 455

Successful Candidates in 1975 Election ---------- 456

Address by President R. F. Bush ---------- 459

Special Features:
- Address—The Transportation Research Board—Its Organization and Functions, by Roy C. Edgerton ---------- 465
- Address—Treatment of Rock Falls on Railway Lines, by F. L. Peckover ---------- 471
- Address—Status Report on the National Rail–Highway Crossing Program—From a Railway Viewpoint, by Patrick J. McCue ---------- 504
- Address—Status Report on the National Rail–Highway Crossing Program—From a Highway Viewpoint, by Henrik E. Stafseth ---------- 509
- Address—Activity Relative to Flood Plains and Potential Effect on Railroad Installations, by D. S. Bechly ---------- 514
- Address—Restoration of Traffic Following Derailment and Fire on Truss Bridge, by N. E. Ekrem ---------- 519
- Address—Railroad Scales—Past, Present and Future Applications, by J. L. Finnell ---------- 523
- Address—The Reading Company's Foreman's Training Course, by E. C. Lawson ---------- 531
- Address—An Outline of the Past, Present and Future of Engineering Training on Canadian National Railways with Emphasis on Roadmaster Training, by J. S. Busby ---------- 536
- Address—FRA, D&RGW, B&LE Joint Study of Track Geometry and Track Degradation, by B. H. Price ---------- 554
- Address—Track Geometry Car—Management Uses, by R. W. Holt ---------- 561
- Address—The Use of Track Analyzer Car Data in Inspection of Track and Maintenance Planning, by Arvie L. Maynard ---------- 573
- Addresses—Engineering Systems Approach to Study for United States Railway Association:
  - Introduction, by Harry R. Davis ---------- 576
  - Organization and Field Work, by H. L. Chamberlain ---------- 578
  - Rehabilitation Planning and Cost Estimating Phase of the USRA Inventory and Assessment Project, by Richard P. Howell ---------- 589
- Address—Heavy Cars—What Are the Issues, by G. H. Way ---------- 616
- Address—Heavy Four-Axle Cars and Their Maintenance of Way Costs, by Robert E. Ahlf ---------- 622

Installation of Officers ---------- 645

AAR Engineering Division Session:
- Remarks by Division Chairman R. F. Bush ---------- 651
- Address—Evolution of Rail Steel and Rail Sections and What is Being Done Relative to This Material Today, by K. W. Schoeneberg ---------- 653
- Report—Fracture Mechanics and Plane Strain Fracture Toughness of Cast Steels, by P. F. Wieser, M. T. Groves and J. F. Wallace ---------- 665
- Address—Truck Hunting—A Cause and Effect of Component Wear in Freight Car Trucks, by L. A. McLean ---------- 687

Report of Executive Director Earl W. Hodgkins ---------- 693

Report of Treasurer A. B. Hillman, Jr. ---------- 703

AREA Constitution ---------- 709

AMERICAN RAILWAY ENGINEERING ASSOCIATION
74th ANNUAL TECHNICAL CONFERENCE

ASSOCIATION OF AMERICAN RAILROADS
ENGINEERING DIVISION
1975 ANNUAL MEETING

MARCH 24–26, 1975

Palmer House, Chicago

PROGRAM

MONDAY, MARCH 24

Opening Session—Red Lacquer Room (4th Floor)—9:30 am

Invocation

Recognition of speakers table guests

Presidential Address—Robert F. Bush, Chief Engineer, Erie Lackawanna Railway

Report of Treasurer—Arthur B. Hillman, Jr., Chief Engineer, Belt Railway of Chicago

Report of Executive Director—Earl W. Hodgkins, AREA

Greetings from Railway Engineering-Maintenance Suppliers Association—John R. Rushmer

Address (Illustrated) by W. N. Carey, Jr., Executive Director, Transportation Research Board, National Research Council

Russian Maintenance of Way Practices (Illustrated)—W. S. Autrey, Chief Engineer System, Atchison, Topeka & Santa Fe Railway

Engineering Division Session—Red Lacquer Room—1:30 pm

Recognition of speakers table guests

Remarks by Chairman R. F. Bush

Remarks by R. R. Manion, Vice President, Operations and Maintenance Department, AAR

Remarks by Dr. W. J. Harris, Jr., Vice President, Research and Test Department, AAR

Progress Report on Track-Train Dynamics Program (Illustrated)
Phase I—E. F. Lind, Director
Phase II—D. Sutliff, Director

Evolution of Rail Steel and Rail Sections and What is Being Done Relative to this Material Today (Illustrated)—K. W. Schoeneberg, Senior Research Engineer, Technical Center, AAR

Fracture Mechanics—Plane Strain Fracture Toughness of Cast Steels (Illustrated) —Dr. P. F. Wieser, Research Director, Steel Founders Society of America, Cast Metals Research Foundation

Truck Hunting—A Cause and Effect of Component Wear in Freight Car Trucks—L. A. McLean, Chief of Equipment Engineering, Seaboard Coast Line Railroad

REMSA RECEPTION—Grand Ballroom—6:30 pm–8:00 pm

TUESDAY, MARCH 25

Technical Session—Red Lacquer Room—8:45 am

Portrait of a Railroad (Motion Picture)

Treatment of Rock Falls Along Railway Lines—Planning and Methods (Illustrated) (Committee 1—Roadway and Ballast)—F. L. Peckover, Engineer of Geotechnical Services, Canadian National Railways

Design and Construction of Classification Yard Buildings for BN Northtown Yard at Minneapolis (Illustrated) (Committee 6—Buildings)—P. W. Peterson, Architectural Supervisor, and S. D. Arndt, Assistant Architect, Burlington Northern, Inc.

National Rail-Highway Crossing Program (Illustrated) (Committee 9—Highways)
Highway Viewpoint—H. E. Stafseth, Executive Director, American Association of State Highway and Transportation Officials
Railroad Viewpoint—P. J. McCue, Executive Director, Highway-Rail Programs, AAR

Activity Relative to Flood Plains and Potential Effect on Railroad Installations—D. S. Bechly, Assistant Chief Engineer Structures, Illinois Central Gulf Railroad

Railway Electrification in Europe (Motion Picture) (Committee on Electrical Energy Utilization)—Introduced by V. W. Pehrson, Vice President, Electrac, Inc.

ANNUAL LUNCHEON—GRAND BALLROOM—12:30 PM

Presentation of those at speakers table

Presentation of newly elected officers

Address by G. W. Maxwell, President and Chief Executive Officer, Erie Lackawanna Railway

Technical Session—Red Lacquer Room—2:30 pm

Restoration of Traffic Following Derailment and Fire on Truss Bridge (Illustrated) (Committee 15—Steel Structures)—N. E. Ekrem, Director-Bridge Engineering, Burlington Northern, Inc.

Development of Track Scales and Their Effect on the Railroad Industry (Illustrated) (Special Committee on Scales)—J. L. Finnell, General Scale Inspector, Louisville & Nashville Railroad

Engineering and Maintenance of Way Training Programs (Illustrated)
Foremen—E. C. Lawson, Chief Engineer, Reading Company
Roadmasters—J. S. Busby, Assistant Chief Engineer—Administration, Canadian National Railways

Journey to Duke Power (Motion Picture on Movement of Nuclear Reactor and Steam Generator from Loading Point to Destination) (Committee 28—Clearances)

WEDNESDAY, MARCH 26

Technical Session—Red Lacquer Room—8:30 am

Use of Track Analyzer Car Data in Inspection of Track and Maintenance Planning —Panel Discussion (Illustrated) (Committee 22—Economics of Railway Construction and Maintenance)

PANEL

T. P. Woll (Moderator), Program Manager, Improved Track Inspection and Data Acquisition Technology, Federal Railroad Administration

B. H. Price, Senior Development Engineer, Bessemer & Lake Erie Railroad—B&LE and D&RGW Efforts

R. W. Holt, Administrator, Engineering Systems, Canadian Pacific Rail—CP Efforts

William Glavin, General Manager, Grand Trunk Western Railroad—CN and GTW Efforts

A. L. Maynard, Engineer Maintenance of Way, Chessie System—C&O and B&O Efforts

Open Discussion

Engineering Systems Approach to Study for USRA (Illustrated) (Committee 32—Systems Engineering)

Organization and Field Work—H. L. Chamberlain, Project Engineer, Sverdrup & Parcel and Associates

Rehabilitation Planning and Cost Estimating—R. P. Howell, Vice President and Chief Railroad Engineer, DeLeuw, Cather Organization

Heavy Cars—What Are the Issues? (Illustrated) (Committee 4—Rail)—G. H. Way, Jr., Assistant to Vice President, Research and Test Department, AAR; and A. S. Lang, Assistant to President—Special Studies, AAR.

Economics of 100-Ton Cars on 4-Wheel Trucks (Illustrated) (Committee 16—Economics of Plant, Equipment and Operations)

Relationship Between Availability of Heavy, High-Capacity Cars and Market for Rail Transportation—Dr. P. H. Banner, Assistant Vice President-Market Research, Southern Railway

Effects of 100-Ton Cars on 4-Wheel Trucks on Design and Maintenance of Equipment—R. E. Taylor, Assistant Vice President-Mechanical, Burlington Northern, Inc.

Relationships Between Heavy 4-Axle Cars and Maintenance of Way Costs—R. E. Ahlf, Manager System Planning-Operation, Illinois Central Gulf Railroad

Installation of Officers

Adjournment

Nominating Committee, 1975 Election

Past Presidents

H. M. Williamson, *Chairman*
Chief Engineer System, Southern Pacific Transportation Company

T. B. Hutcheson
Assistant Vice President, Engineering & Maintenance of Way, Seaboard Coast Line Railroad

E. Q. Johnson
Senior Assistant Chief Engineer, Chessie System

A. L. Sams
Vice President, DeLeuw, Cather & Company

D. V. Sartore
Chief Engineer—Design, Burlington Northern, Inc.

Elected Members

E. M. Cummings (East)
Regional Assistant Chief Engineer, Chessie System

A. C. Parker, Jr. (South)
Chief Engineer, Maintenance of Way, Louisville & Nashville Railroad

J. R. Williams (West)
Bridge Engineer, Chicago, Rock Island & Pacific Railroad

W. T. Van Deventer (Canada)
Regional Chief Engineer, Canadian National Railways

N. E. Ekrem (At Large)
Director—Bridge Engineering, Burlington Northern, Inc.

Committee of Tellers, 1975 Election

The following committee was appointed to canvass the ballots for Officers and Directors and for Members of the Nominating Committee, the count being made on February 21, 1975.

W. S. Stokely, *Chairman*
N. E. Whitney, Jr., *Vice Chairman*
L. R. Beattie
L. E. Brault
J. Budzileni
W. F. Burt
R. A. Dugan
D. F. Fancher
E. H. Hofmann
D. J. Lewis
G. W. Mahn, Jr.
T. E. Markvaldas
T. M. Niemeyer
L. S. Richards
P. H. Swanson
R. Urband
J. W. Vician
D. R. York
K. V. Zukas

Successful Candidates in 1975 Election

FOR PRESIDENT

J. T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, Jacksonville, Fla.

FOR SENIOR VICE PRESIDENT

John Fox,* Assistant Chief Engineer, Canadian Pacific Rail, Montreal, Que.

FOR JUNIOR VICE PRESIDENT

B. J. Worley,** Vice President-Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago

FOR DIRECTORS

East:

William Glavin, General Manager, Grand Trunk Western Railroad, Detroit, Mich.

West:

E. H. Waring, Chief Engineer, Denver & Rio Grande Western Railroad, Denver, Colo.

G. H. Maxwell, System Engineer of Track, Union Pacific Railroad, Omaha, Neb.

Canada:

R. L. Gray, Chief Engineer, Canadian National Railways, Montreal, Que.

FOR MEMBERS OF 1975 NOMINATING COMMITTEE

East:

J. E. Sunderland, Regional Assistant Chief Engineer, Chessie System, Pittsburgh, Pa.

South:

D. S. Bechly, Assistant Chief Engineer—Structures, Illinois Central Gulf Railroad, Chicago

West:

L. C. Collister, Manager—Tie and Timber Department, Atchison, Topeka & Santa Fe Railway, Chicago

Canada:

Bernard Fast, Assistant Regional Engineer, Canadian Pacific Rail, Winnipeg, Man.

At Large:

C. L. Gatton, Assistant Chief Engineer—Maintenance of Way, Louisville & Nashville Railroad, Louisville, Ky.

---

* Elected Junior Vice President in 1975 election, but advanced to Senior Vice President by election by Board of Direction to fill vacancy, according to AREA Constitution. Will serve one-year term as vice president.

** Elected Junior Vice President by Board of Direction to fill vacancy, according to AREA Constitution. Will serve two-year term as vice president.

PRESIDENT'S ADDRESS

Address by President R. F. Bush*

I appreciate the honor and opportunity you have given me to serve as president of your Association. My special thanks to the other officers and members of the Board of Direction who have given so freely of their time and talents during their tenure of office, and especially during the last year, in conducting the affairs of your association.

The Annual Technical Conference provides all of us an opportunity to exchange information and ideas with other members and with guests. Primarily, however, it is a time to hear first hand, papers and reports from some of the people who have seen railroad operations in other countries, made studies or performed research work to provide additional knowledge and answers to some of our current engineering and maintenance problems.

In order to provide more members of the AREA and guests an opportunity to hear such reports and papers, your Board of Direction established the Regional Meetings to supplement the Annual Technical Conference. To date we have had 10 meetings held in various parts of the United States and Canada. The first Regional Meeting was held in Portland, Oregon, in 1965. The last meeting was held in Kansas City, Missouri, on November 6, 1974. C. E. Weller, a director of the Association and assistant vice president—engineering of the Chicago, Rock Island & Pacific Railroad, was chairman for the last meeting. He and his staff provided a very informative and worthwhile program. Some of the papers delivered at that meeting are included in Bulletin 651, January–February, 1975, Proceedings Volume 76. My thanks to Mr. Weller and his staff for working out the arrangements and their time and effort to make this Regional Meeting possible. He was aided materially by George Curtis and his staff at Servitron, Inc., Consulting Engineers. A total of 195 members and guests attended the Kansas City Regional Meeting.

Our next Regional Meeting will be held in the Hotel Vancouver, Vancouver, British Columbia, Canada, on October 30, 1975. John Fox, assistant chief engineer of Canadian Pacific Rail, and vice president-elect of AREA, is chairman. This is a beautiful part of Canada and with a program being planned that will add to our professional knowledge, I hope all of the members and others in the western part of Canada and the northwest part of the United States will attend. All members and non-members anywhere in the United States and Canada will be more than welcome if they can attend.

During the year from our last Technical Conference, our membership has increased by 78 and our present membership is 3469. I am glad to report your Association is in a good financial position. We, of course, are interested in providing the benefits of membership in the AREA to more people, whether they are in the railroad industry, university professors, supply industry, or government officers, consulting engineering firms, and similar organizations. These people by becoming members can help the Association in advancing the knowledge pertaining to the construction and maintenance of railroads. I sincerely hope each of you will introduce more of your friends and associates to the aims and benefits of the AREA so that they will become members.

---

* Chief Engineer, Erie Lackawanna Railway, Cleveland, Ohio.

Our very capable executive director, Earl Hodgkins, and treasurer, Art Hillman, will provide you with more information about your Association when they give their reports.

Preceding our Regional Meeting at Kansas City, the Board of Direction met with chairmen and vice chairmen of the AREA technical committees. This was a very informative meeting and provided all of us a chance to discuss and analyze some of the problems of the committees. Several points were made, and I would like briefly to bring these to your attention:

(1) Some members, while serving on several subcommittees and committees, are not participating in preparing reports on committee assignments. This is unfortunate because our committee reports form the basis of the recommended practices contained in the two volumes of the AREA Manual for Railway Engineering (Fixed Properties) and the Portfolio of Trackwork Plans.

(2) Inactive members are being retained on committees. I know it is not always possible to attend all committee meetings, but answering correspondence and presenting your ideas is a must if the committee work is to be completed on time.

(3) It appears some committee assignments are inactive and have been for some period of time. Also, committees with 9 or 10 assignments are only actively working on 3 or 4 assignments.

(4) There is a real need for committees to follow the procedure set up in the manual for committee activities for collaboration with other committees.

(5) Committee members should, if they are not doing so, interview the maintenance-of-way and construction officers of their railroads as to subjects for committee assignments.

In summary, there should be fewer but more interesting subjects for study by the various committees, more active member participation in the committee assignments and definite progress reported by each sub-committee and committee on the assignments.

Considering the reduction in revenues and the resulting reduced maintenance-of-way and structure budgets on most railroads, it is necessary that we find the ways and means to reduce costs and provide more economical methods to maintain our railroads. The purchase of materials is a large portion of our maintenance-of-way budget. One way to reduce these costs and eliminate the manufacture of many different types of the same basic item is standardization. Our technical committees have, as a result of their assignments, produced standard plans for track materials used on all railroads. The Trackwork Portfolio contains many such recommended plans and specifications. However, frogs are still being ordered with leg rails a little longer or a little shorter than the AREA design, and tie plates are being punched differently and of a different size than those shown in the AREA Manual. The rail drillings are also different from those recommended by our committees. All of these variances from the AREA recommendations are costing more to produce because of a multitude of patterns, tool changes and set-ups at the shops of the steel companies and fabricators. I believe it is time each of us examined our own standards and determine if we can adopt the already prepared AREA plans and specifications for track materials; after all, many of us have had a hand in developing them. I wish I could translate the effect of standardization into dollar savings, but this is impossible. However, I believe we can all agree a standard item will cost less than the custom-made ones.

A very sincere thank you from our Association to our many good friends in the supply industry for their excellent cooperation and assistance during the past year. They have through development, tests and research improved and advanced the techniques and machines required to improve the efficiency of our maintenance and construction program.

No conference can proceed so smoothly year after year as the AREA Conference does without a great deal of hard work by many people. I would like to convey to M. B. Miller, engineer—high speed ground transportation, Penn Central Transportation Company, who is the manager of the Conference Operating Committee, and to all the members of the committee, my personal appreciation and thanks for their usual outstanding job.

The advance planning, scheduling and arrangements for the Conference are made by our executive director, Earl Hodgkins and his competent and very capable staff. My thanks to you, Earl, and to your staff.

As I mentioned previously, we are honored to have so many lovely ladies with us this morning. They make a wonderful contribution to the success of the Conference. I particularly want to express my appreciation to my wife, Fran, Ruth Hodgkins and to the ladies who have assisted in arranging and conducting the ladies program. It has been a very rewarding experience for Fran and me to work together in our respective duties preparing for this important occasion.

SPECIAL FEATURES

The Transportation Research Board—Its Organization and Functions

76–653–1

By ROY C. EDGERTON
Assistant Director for Technical Activities
Transportation Research Board
National Research Council

It is a pleasure to be here and an honor to have an opportunity to address this meeting. As you know, I am here as a substitute for W. N. Carey, Jr., executive director of the Transportation Research Board.

My task here, as I see it, is to tell you something about the Transportation Research Board with the hope that the description might help to define the role that the Board might play in the rail transport community.

The Transportation Research Board is an element of the National Research Council which is described as the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations. From its establishment in 1921 as the Highway Research Board until last fall, the Board operated under the Division of Engineering. As a result of a reorganization of the Council, we are now under the Commission on Sociotechnical Systems.

On March 9, 1974, after years of progressively increasing activity outside the highway field and with the concurrence of our sponsors and supporters, the Governing Board of the National Research Council approved the change of our name from the Highway Research Board to the Transportation Research Board.

Our purpose is to advance knowledge concerning the nature and performance of transportation systems, through the stimulation of research and the dissemination of information derived therefrom.

The guiding element of the Board is an Executive Committee with members from state and federal agencies, industry, the consulting field and the academic community. This year, Milton Pikarsky of the Regional Transportation Authority is chairman and Professor Harold Michael of Purdue is vice chairman. L. S. Crane of the Southern Railway System is a member and your past president, Bill Hedley, here at the head table, is a former member. The Board operates in three technical divisions with separate but interrelated programs.

I will mention first the National Cooperative Highway Research Program which is identified as Division D in the Board's structure. Since the 1930's, 1½ percent of the Federal Aid Highway funds have been earmarked for Highway Planning and since 1962 for Highway Planning and Research. These funds support highway planning efforts in the state highway and transportation departments and pay for most of their research programs. Operating through the American Association of State Highway and Transportation Officials, the states have elected to pool 4½ percent of these funds to support research on problems of concern to most of the states and involving larger expenditures than one state alone would be able to support. The sponsors, the state highway and transportation departments, identify the prob-

---

Note: Discussion open until October 15, 1975.

lems for research. The NCHRP element of TRB then expresses these problems in researchable terms, advertises them to the research community, selects the best qualified agencies to perform the research, monitors the research and reviews and publishes the reports. This program utilizes the services of many highly qualified people who serve on panels to select research agencies and review the reports. The annual total budget for the program is about 3.5 million dollars of which about 80% goes for research contracts. The rest supports staff and panels activities and the publication of reports.

Since the program was started in 1962, it has produced more than 150 research reports. To select one area in which you might be interested, bridge weldments, two reports, "Effect of Weldments on the Fatigue Strength of Steel Beams" and "Fatigue Strength of Steel Beams with Welded Stiffeners and Attachments" have been published, and two projects, "Acceptance Criteria for Electroslag Weldments in Bridges" and "Welded Steel Bridge Members Under Variable-Cycle Fatigue Loadings" are underway.

Division B of the Board is called Special Projects. This includes two major activities. The smaller in personnel and expenditure is synthesis of information. The first synthesis program that I will discuss has a rather general scope. Through the efforts of staff members, an advisory panel and usually a consultant, the available information on a rather narrow problem area is brought together. Published and unpublished research results, experience and the informed practice all contribute to a concise report that gives the best approach to the problem. Some of the reports are:

No. 4	Scour at Bridge Waterways
No. 8	Construction of Embankments
No. 18	Erosion Control on Highway Construction
No. 23	Getting Research Findings into Practice

When the program started in 1968, a budget allocation of $100,000 paid for four syntheses each year. The budget is now $200,000, but with inflation the output is six or seven a year.

There is a similar synthesis drawing together information on highway and transportation law.

Both of these efforts are funded as projects in the National Cooperative Highway Research Program that I described previously.

The major function of Division B is development, operation and coordination of the Transportation Research Information Services, a group of computer-based information storage and retrieval systems. The original member of this group is the Highway Research Information Service (HRIS). In operation since 1964, it now contains some 61,000 items, either abstracts of documents or summaries of on-going research. HRIS is supported as a general activity of TRB. These funds come from the state highway and transportation departments, the Highway and Urban Mass Transportation Administration of DOT, individual and organizational supporting memberships, registration fees and sale of publications. The service provides information in several different forms. It produces periodic publications of abstracts received and of summaries of on-going research. It provides packages at intervals in response to standing orders and it provides print-outs from searches based on subject areas or word combinations. An allocation of free service is provided to the principal financial supporters of the service. The use of the service is available to others on a fee basis.

The Maritime Research Information Service (MRIS), operated jointly by TRB and the Maritime Transportation Research Board, another NRC element, contains about 9,000 items. It is supported by the Maritime Administration and has capabilities similar to HRIS. Arrangements are underway with the Federal Aviation Administration to support an Air Transportation Research Information Service (ATRIS). So far, 2,000 items have been entered for this service.

Of principal interest to this audience would be the Railroad Research Information Service (RRIS) which has been in operation since 1972 with support from the Federal Railroad Administration and now contains about 8,000 items. RRIS has retrieval capability similar to HRIS and produces the Railroad Research Bulletin twice each year. Each issue contains both summaries of on-going research and abstracts of published reports. The use of the service is available for a fee. James H. Seamon, who was the original staff member for the service, has been transferred to an assigment that I will describe later, and Frederick N. Houser, Jr. has taken over the job.

In addition to the work of HRIS, MRIS, RRIS and ATRIS, TRB maintains a Committee on Transportation Research Information Systems (TRIS Committee). This Committee has developed the design and plans for a national network of transportation research information services (TRISNET). Dr. William J. Harris, Jr. of AAR was chairman of this committee for its first two years and had a key role in the development of RRIS and the TRISNET plan. In addition to the modal services, it is planned that TRISNET will include an on-line retrieval center, a communications center, and transportation libraries. The TRIS Comittee and TRISNET development work at TRB are sponsored by the Office of the Secretary of Transportation at the rate of approximately $120,000 per year, and we hope that funding will be provided to continue the development and to operate the system. The one TRISNET activity now operational on a prototype basis is on-line retrieval. Fred Houser has a remote console set up here in the hotel. Through it you can query the on-line file which includes an RRIS component.

Division A, the other technical division of the Board, is called Regular Technical Activities. If you have noticed that I have failed to account for Division C, it takes care of administration. The regular technical activities include the support of some 180 committees, councils and task forces with about 2400 members. These committees are involved in a complex structure that I won't describe except to list seven of them with the hope that these names will give you an idea of the total scope that the committees cover. These are a sample:

Eminent Domain and Land Use,

Citizen Participation in Transportation Planning,

Photogrammetry and Aerial Surveys,

Chemical Additions and Admixtures for Concrete,

Mechanics of Earth Masses and Layered Systems,

Railroad-Highway Grade Crossings, and

Snow and Ice Control.

In general, each committee is assigned the same sort of activities, the difference being assigned scope or interest area. These are the things that each committee is asked to do:

Identify Research Needs and Priorities,
Stimulate Needed Research,
Advise on Research Procedures,
Review Papers for TRB Meetings and Publications,
Evaluate and Interpret Research Findings,
Encourage Implementation Where Appropriate,
Sponsor Conferences and Workshops, and
Provide for the Exchange of Information.

Collectively, these committee activities produce the program for the Board's Annual and Summer meetings and for its many conferences and workshops, and this in turn produces most of the material for our regular publication program. In addition, the staff of Division A follows a schedule of visits to maintain contact with operating and research agencies and universities. I mentioned the sources of support for regular technical activities when I described the Highway Research Information Service.

Through the years, the Board has undertaken more and more activities that have gone beyond the highway interest. These have included airport pavements since the 1940's, Urban Planning and Urban Transportation Planning since the 1950's and Urban Mass Transit in recent years. In addition to this, much of what the Board has done in the past has application outside the highway field. The synthesis report and committees that I mentioned may sound as appropriate to you as they do to those who generated the studies and organized the committees.

Other areas in which work might have equal application are soils, drainage, materials of all kinds common to the two modes, structures, coordination with the community and protection of the environment. A conference on statewide transportation planning recognized as a deficiency that it lacked representation from the railroad interests.

About 1920, when highway administrators found that the highway systems that they had built had to be maintained, many adopted railroad maintenance management procedures including names and titles. In recent years, much time and effort has gone into improving highway maintenance organization and management. I understand that those involved from the two modes have begun to share their experiences.

When we were formally designated the Transportation Research Board, our Executive Committee directed the formation of a special committee to explore and recommend activities that the Board should undertake in rail transport. The specific tasks of the committee are:

1. To learn what TRB (HRB) is and what it has done and plans to do in general.
2. To learn what TRB already does specifically of interest to the rail community.

3. To determine what other agencies (government or non-government, outside the NRC) do that need not be duplicated.
4. To recommend to the Executive Committee what TRB should do in the rail field to fill gaps.
5. To suggest appropriate level of activities, budget and potential sources of funds to accommodate new activities in the rail field.

This committee is chaired by Dr. Harris and includes people with broad experience in many facets of the rail community. Several members of the committee have been involved in previous Board undertakings and know of its capabilities. This study has been underway since last summer, and the Executive Committee awaits with great interest a report expected later this year. As Rail Transport Specialist on our staff, Jim Seamon is Secretary and Staff Representative for the committee. All of us with the Board have appreciated the sincerity and enthusiasm with which Dr. Harris and the committee members have undertaken their task.

While the committee has not made its report, there have been two notable by-products from its deliberations. An interesting session on Transportation and Floodplains at the Board's 54th Annual Meeting last January grew out of a committee recommendation that we give attention to that subject. The proceedings of the session are being prepared for publication. We hope to get this out by the end of the year. I see that D. S. Bechly of the Illinois Central Gulf Railroad, who gave an excellent report from the railroad viewpoint on the session, will address you on that subject later in this conference.

Another Board activity to come out of what we call the Railroad Overview Committee will be a 5-week conference on railroad research needs at the National Academy of Sciences conference center at Woods Hole, from June 30 to August 1. The objective of this conference, which is being supported by the Association of American Railroads and the Federal Railroad Administration, will be to produce a document outlining railroad research needs and priorities for the next 5 to 10 years.

At this point, I would like to come back to our purpose and comment on the sorts of things that the Board does and doesn't do. You will recall that our real job is to stimulate research and disseminate information derived from research.

We don't prepare nor maintain specifications nor do we establish policy nor attempt to influence legislation. We have in many instances, produced objective information that others have used for those purposes. There has been a convenient arrangement in the highway field in the past with the American Association of State Highway Officials, now Highway and Transportation Officials, looking after specifications, policy and legislative action, using, at times, information developed by the Highway Research Board. A similar relationship might be developed with organizations involved with the railroad industry. A recent example of another type of Board activity might be of interest. At the direction of Congress, the Urban Mass Transportation Administration prepared guidelines for the evaluation of transit alternatives to be used in evaluating proposals for federal support of capital investment. Prior to the publication of these guidelines in the Federal Register, UMTA asked the Board to assemble a representative group of state and local transit administrators and operators and other knowledgeable and interested people to review the guidelines and develop a consensus of their potential impact on the future of transit operation. This consensus was presented to the Administrator in the final session and is being prepared for publication.

Finally, I would like to say a word about where we think the Board is going. Another overview committee of composition comparable to the one that I have described is exploring our involvement in Air Transport. We have had a number of requests to get started in Inland Waterway Transportation and we are setting up a committee to look at this. There have been expressions of interest concerning pipelines but we really have nothing going there yet.

Looking back at the street and highway system, which has been the focus of our interest for so long, the present emphasis seems to be on improving the capacity and utility of the existing system and in making transportation better meet the needs of our society.

Thanks for the opportunity to tell you about our organization.

Treatment of Rock Falls on Railway Lines

76–653–2

By F. L. PECKOVER
Engineer of Geotechnical Services
Canadian National Railways

CONTENTS

Page

1. INTRODUCTION 472
2. OCCURRENCE OF ROCK FALLS 472
3. COSTS VS. SAFETY 473
4. APPROACHES TO A SOLUTION 473
   4.1 Past Practice 473
   4.2 North American Highway Practice 474
   4.3 Foreign Railway Practice 474
5. STABILIZATION MEASURES 475
   5.1 General 475
   5.2 Scaling and Trimming 475
   5.3 Rock Blasting 475
   5.4 Design of Slopes 476
   5.5 Drainage 476
   5.6 Prevention of Weathering 476
   5.7 Support and Restraint Systems 477
6. PROTECTION MEASURES 477
   6.1 Characteristics of Rock Falls 477
   6.2 Track Relocation 478
   6.3 Intercepting Ditches on the Slope 478
   6.4 Shaped Ditches 478
   6.5 Wire Mesh Blankets 479
   6.6 Catch Nets and Fences 479
   6.7 Catch Walls 479
   6.8 Rock Sheds and Tunnels 480
7. WARNING MEASURES 480
8. ORGANIZATION OF WORK 480
   8.1 Policy 480
   8.2 Annual Program and Priorities 481
   8.3 Choice of Treatment Methods 481
   8.4 Records 482
   8:5 Staff 482
   8.6 Contract Work 483
   8.7 Liaison with Others 483

References 483

Tables 484

Figures 488

Note: Discussion open until October 15, 1975.

1. INTRODUCTION

Track safety has received increased attention from railway management in recent years. This is partly due to government directives but also due to good management practice which requires reliable track to handle increasing traffic on dependable schedules.

This paper deals with an aspect of track safety on which little information has been available—how to combat the hazard of rock falls on track in rugged and mountainous territory. It is based for the most part on a study made by Canadian National Railways to answer this question in the case of their south main line through the mountains of British Columbia (Fig. 1) between Jasper and Vancouver (Peckover 1972). The study involved visits and discussions with railway engineers and others in Canada, the United States and several other countries. As a result, the information given is based on the experience of many organizations with similar problems, and the author's views on the applicability of this experience to North American railway operations.

It is of interest to note that a comprehensive text on "Landslides: Analysis and Control" is in preparation by the Transportation Research Board (1975) of Washington. It will provide much valuable detailed information on problems of both earth and rock slopes. The paper following deals with the subject of rock falls as they concern the railway engineer.

2. OCCURRENCE OF ROCK FALLS

Rock falls occur when a rock or group of rocks dislodge from a face or slope (Fig. 2). Unstable rock masses are often broken, and failures usually involve individual rocks or relatively small rock masses. Rock material accumulated in gullies also slides down to the track, often under the influence of heavy rains and sometimes combined with mud. (Fig. 3).

Rock instability may be caused by surface factors such as chemical weathering, temperature variations, frost wedging, running water, and vegetation; or by subsurface factors such as residual stresses from rock distortion, orientation of structural defects, and water pressures in the joint system.

A factor which is not significant compared to others is the disturbing effect of rail traffic. If relative masses are compared, traffic-induced vibrations are seen to be extremely small, even in rock slopes next to the track. The frequency of rock falls hitting long freight trains is no higher than would be expected from the proportion of total time that they occupy track.

Two of the factors mentioned are worthy of note:

- *Pressure from ground water* in joints and fissures. In a slope 100 ft high, a joint filled with a small amount of water, readily available from rainfall or melting snow, will exert a pressure of more than 150 tons per foot of slope width. Such conditions often occur during freezing weather when normal drainage from fissures is blocked by ice.
- *Frost wedging* caused by the expansion of water turning to ice during freeze-thaw cycles which occur during some periods of spring and fall.

The important influence of weather is evident in Fig. 4 where the total number of rock falls for each month of the year over a 38-year period on the Yale Subdivision of the CN south line is plotted against rainfall and temperature. It is seen that:

- Maximum frequency of rock falls occurs in January and again in December when mean temperature is about 32 F and freeze-thaw cycles are taking place.
- When the temperature is above freezing, frequency of rock falls varies fairly directly with amount of rainfall.

3. COSTS VS. SAFETY

The cost of rock falls is the total cost of track maintenance required (scaling, clearing ditches, etc.), patrols, train delays and rerouting, and damage to equipment and property due to accidents. Although these costs are substantial, an analysis will show that even higher annual costs are involved in an effective program to guard against rock falls. A program of protection cannot necessarily be justified on the basis of return on investment. The consideration which tips the balance in favor of action is the matter of personal safety.

A review of accident records for the CN Mountain Region, comprising most of Alberta and British Columbia, showed that:

- Rocks on the track caused more total deaths and injuries than any other type of accident except level crossings.
- Rocks on the track caused a higher ratio of deaths to injuries than *any* other type of accident.

The latter fact, which is probably due to the unparalleled derailing and stopping power of rock masses on the track, helps to explain the deep concern of men in the running trades toward the rock problem.

4. APPROACHES TO A SOLUTION

4.1 Past Practice

The traditional approach in North American railway practice until recently has been that:

- Rock falls are acts of God which cannot be foreseen, and therefore,
- The best solution is to carry out regular scaling of loose rocks, install electric warning fences and rock sheds when justified by the occurrence of particular accidents, and operate track patrols in very dangerous areas.

These measures have been reasonably successful for a long time. However, with today's increasing traffic and track occupancy they are not sufficient. In many cases we can no longer tolerate the delays involved in stopping traffic when we think that rocks may be on the track. This can be called a negative or passive approach. The positive or active approach would be to *prevent* rocks from reaching the track, and there are of course ways of doing this. In recent years important advances with rock stability problems have been made in the construction, highway and mining fields. This new knowledge is only beginning to be used to increase the odds against accidents in railway operation at dangerous locations.

Considering all alternatives, a dangerous rock fall location can be dealt with in three ways:

- *Stabilization*, or preventing rocks from moving out of place unexpectedly, such as with rock scaling and bolting,
- *Protection* of track, or keeping rocks which do move out of place from reaching the vicinity of track, such as with walls or rock sheds, and
- *Warning*, or signalling traffic when rocks arrive at the vicinity of track, as by electric fences.

4.2 North American Highway Practice

Highways can assume a greater degree of risk from rocks on their right-of-way than can railways. As cars and trucks can brake relatively rapidly and steer around obstacles, occasional falling rocks are often acceptable as long as warning signs are posted.

In spite of this approach, highway engineers have developed a variety of methods of dealing with unstable rock slopes. A review of these methods shows that emphasis is entirely on stabilization of slopes and physical protection of the road. Detection and warning systems are almost non-existent.

It should be noted that on highway rock slopes, the time, access and space available for remedial work are often much greater than for similar work on railways. For this reason, methods and costs of highway work are not always applicable to our problems. It is of particular interest then to compare the approach of railways elsewhere to the rock fall question.

4.3 Foreign Railway Practice

The foreign railways contacted are listed in Table 1 along with a description of their approach to rock-fall problems. All these organizations have high levels of technology and at least as high a traffic volume on their mountain lines as we find on this continent. Many of their lines were built 60 to 90 years ago when skilled labor was cheap. Many masonry walls and structures to control rock falls were built as a part of original construction and are serving well today. These are maintained and added to as required, along with additional stabilization and protective work. In fact, the overall emphasis on remedial work as compared with warning systems is in marked contrast to the traditional approach of American and Canadian railways.

Warning systems are not used at all in five out of seven of these railways. From the time of initial construction, it appears to have been the firm intent that no rocks should reach the track. With this approach, warning systems are considered redundant. As an important corollary, it is established that good stabilization and protection methods do work at reasonable cost. A general record per railway of one accident due to rock falls every 5 to 15 years gives convincing evidence of this.

A particularly interesting case is Switzerland where many valley slopes are high and steep, and the points of origin of many rock falls are inaccessible for stabilization. In these circumstances, a great deal of protective work has been done in the form of walls, arch bridges over rock slide gullies, "dikes" to divert slides into safe areas, along with frequent sheds and tunnels. More recent work includes concrete walls and buttresses, and rail walls, sometimes on top of masonry walls. The number of trains per day on all Swiss lines averages 80, with 130 on the Bern–

Lotschberg–Simplon line, and 300 on the St. Gotthard Tunnel line. The maximum free track time which can be arranged for maintenance on the latter is 2½ hours.

For information, Table 1 includes CN's current program to combat rock falls, much of which has developed as a result of this study.

The methods used by these foreign railways to combat rock falls give us some idea of what can be done to achieve reliable service with high density traffic in mountain terrain. Available methods are reviewed concisely below. A more detailed description is given in Piteau and Peckover (1975).

5. STABILIZATION MEASURES

5.1 General

Stability analysis of rock slopes, a complex procedure, will rarely be needed because rock slopes as a whole are usually stable. It is the individual blocks of rock on a slope that require stabilization and normal analyses do not apply to these. However, stability studies of portions of a slope will sometimes be needed for the design of support systems.

Stabilization methods may be grouped as

- excavation, to remove unstable material or form a stable slope,
- drainage, to reduce internal water pressure,
- surface protection, to retard weathering, and
- support and restraint systems, to strengthen rock masses.

5.2 Scaling and Trimming

The excavation of loose rock from faces and slopes is a basic maintenance operation, carried out on all transportation routes in rocky terrain.

Scaling is usually done by men working on ropes with hand pry bars and explosives. The rate of work is slow of necessity. Mechanical equipment is more efficient and safe, but limitations of access to parts of the slope are severe. The frequency and amount of scaling done each year is governed by the amount of maintenance money available. In fact, many locations should be scaled annually but are not.

Trimming involves drilling, light blasting, and scaling to remove small ragged areas of rock where repetitive scaling would otherwise be required. Scaling and trimming should be started in spring when frost leaves the rock. Each location should be thoroughly inspected by an engineering geologist and the rock foreman before work begins, and during its progress at difficult locations.

To establish how the best contract work can be obtained, the work of different contractors should be compared in quality as well as quantity.

At many places where rock is shattered or tends to weather rapidly, the interval between scaling cycles can be considerably extended by cleaning with water or air jets after scaling and applying a layer of shotcrete. Fig. 5 shows a rock face which has been treated in this way.

5.3 Rock Blasting

Many current difficulties with unstable rock slopes on rail lines are due in good part to heavy blasting at the time of original construction. In new construction, the use of presplit blasting (Bureau of Public Roads 1966) is of major benefit in minimizing rock shattering. *Presplit blasting* uses light charges with millisecond delays in closely spaced holes, giving a clean rock face as in Fig. 6. Presplitting reduces weathering of rock and hence scaling costs, allows use of steeper slopes with lower excavation quantities, minimizes overbreak, reduces the final slope dressing required, and improves appearance. Fig. 7 shows a successful application. Its disadvantages are that techniques cannot be standardized because of the variables involved, and its proper application requires good geological information and an experienced person to plan the work.

5.4 Design of Slopes

A major source of difficulty in existing rock cuts has been the use of standard cut sections for all slopes, regardless of the condition and structure of the rock. Fig. 8 gives an example where the use of standard slopes could cause serious continuing rock falls.

The use of variable slopes, benches below layers of rapidly weathering rock and structural support where necessary, combined with correct blasting techniques, can practically eliminate rock falls in new cuts. Such methods as these are used as a routine by all highway departments in Canada and the United States and by most railways in Europe. Rock slope design procedures are described by Piteau and Peckover (1975).

5.5 Drainage

The important effects of water pressure on the stability of rock slopes are discussed by Patton and Deere (1971). Areas behind the top of unstable slopes should be thoroughly inspected and any water flowing toward the slope or into the ground should be diverted to adjacent gullies or stable portions of the slope. Where feasible, the bed of water courses behind a slope should be paved.

As the effectiveness of drains in the face of a slope depends on the size and orientation of rock joints, the angle and depth of drilling should be chosen by an engineering geologist. Rock faces from which water is already freely flowing need not be drained artificially. On the other hand, a drain does not have to produce any noticeable flow of water to be effective; it may only flow under extreme conditions.

Where seepage on a rock face causes ice to form and become a hazard to track, drain holes should be drilled from the base of the slope upward and inward to intercept flow. The outlet of drains should be covered with insulating material to prevent freezing.

5.6 Prevention of Weathering

Shotcrete, a basic tool in the treatment of unstable rock slopes, can be used to prevent weathering of rock surfaces and provide structural support. It consists of mortar with aggregate up to ¾-inch in size, projected by air jet directly on the surface to be treated. The process has largely replaced gunite, a similar method using smaller aggregate. While there are many locations where shotcrete may be applied to advantage, they should be selected with specialist advice.

Shotcrete practice is reviewed in a publication of the American Concrete Institute (1974). Its service life can be substantial—West German Railways have applications over wire-mesh reinforcing which have been in use for 40 years and have an expected life of 70 years. Fig. 9 shows an 18-year-old application of gunite which has not required maintenance.

Failures of shotcrete are caused by internal water pressures, frost action, or poor bond with the rock. Drainage is usually provided by short plastic pipes inserted in cracks or holes drilled into water-bearing rock. An example of a failure due to poor drainage and too thin a coverage of mortar is shown in Fig. 10.

5.7 Support and Restraint Systems

Support systems provide strength by applying direct support (as with buttresses, retaining walls, and rock dowels) or direct compression (as with rock bolts). *Restraint systems* keep rocks from loosening enough to fall (as with cables or wire mesh). Support and restraint systems are often combined (as with wire mesh bolted in place).

Buttresses provide a simple, effective and permanent support under large rocks in danger of falling, not only at the ditch level but anywhere on a rock face as needed. Often such rocks are not scaled down because they may release considerable material above them (Fig. 11). Buttresses can be made of concrete, or shotcrete built up in successive layers, and sometimes combined with rock anchors for better stability.

Rock bolts and dowels are basic tools in supporting rock masses. *Rock dowels* are grouted into drilled holes in rock to act in the same way as reinforcing rods in concrete. They are not tensioned and therefore only offer resistance when the rock tends to move. An application is shown in Fig. 12. *Rock bolts* on the other hand are tensioned to compress the rock mass and increase the friction between blocks. They and the rock together thus act like a stressed concrete beam or arch.

Bolts and dowels are effective and versatile but must be used with care. They are expensive to install on a slope because of access difficulties and require experienced judgment, both in deciding on their economies for a particular site and on the optimum location and depth of each unit. Installation should be done by thoroughly experienced contractors and closely supervised.

Rock bolts and dowels can be used in many ways:

- alone, to fasten large rocks
- with strapping or bearing pads to fasten small blocky rocks
- with wire mesh and sometimes shotcrete to stabilize broken rock zones
- to anchor buttresses, or beams or slabs placed below sloping layers and blocks of rock (as in Fig. 13)
- to anchor retaining walls or cribs where space beside the track is insufficient for gravity walls
- to anchor cables and nets to restrain individual rocks or rock masses.

6. PROTECTION MEASURES

6.1 Characteristics of Rock Falls

Track protection methods are to keep loose rocks from landing on the track. Before the best method of protection can be chosen at a particular spot, it is important to have some idea of how rocks arrive at the track. They may fall free, bounce, roll or slide down the slope. The manner of their arrival depends on the shape of individual rocks and particularly on the angle of the slope as shown in Part (1) of Fig. 14 from Ritchie (1963).

With *free-falling rocks,* the only practical means of protection is to move the track away while preventing the rocks from bouncing or rolling after landing, or to build a rock shed.

The path of *bouncing rocks* is difficult to predict. Interception above the track requires a high "reach" with a wall or net.

Rolling or sliding rocks are easiest to intercept as their path is in contact with the slope. When rolling down gullies, their path is even more predictable.

In all cases the method of protection must allow for:

- The sizes of rock involved, as the cost of protection increases rapidly with increasing size.
- The rate at which fallen rock accumulates. Storage without encroachment on track must be provided for the rocks likely to arrive during a reasonable maintenance interval.

6.2 Track Relocation

Relocation is feasible when space is available on the outer side and track alignment allows. When combined with ditch shaping (see Item 7.4) it can give an economical solution to the problem of free-falling rocks.

6.3 Intercepting Ditches on the Slope

Where a talus slope extends down to the track, rolling rocks can be caught by a shallow ditch excavated diagonally across the slope. This method assumes that a talus slope can safely be cut steeper than it is standing, and this is found to be generally true. But the ditch must be shaped carefully by bulldozer so that the upper slope is never, even momentarily, steeper than planned by a geotechnical engineer. Two designs of intercepting ditches on the slope are sketched in Fig. 15. At some locations, such ditches can be used to intercept rock falls and steer them into disposal areas at one side.

6.4 Shaped Ditches

Roadside ditches can be deepened and shaped to prevent rocks from reaching the track. An example of this, effective for rolling stones, is shown in Fig. 16.

Ditch depth and width, steepness of the track side slope, and storage volume are all important, and the choice of each should take into consideration the behavior of the falling rocks. Ritchie (1963) evaluated the ditch depth and width factors and the slope characteristics as in Part 2 of Fig. 14 which is a State of Washington standard for new road construction.

At many locations there is not enough space beside the track for the ditch widths recommended. However, the trackside slope of the ditch can be made vertical to retain rolling rocks by installing a gabion or tie wall as shown in Part (1) of Fig. 17, or the storage volume of the ditch can be increased by excavating a catchment area at the base of the slope as in Parts (2) and (4) of the figure. Especially at the base of gullies, this can prevent rock debris from encroaching on track.

If there is a large accumulation of rock, a catch wall on the track side of the ditch may be needed as well.

No bedrock should remain exposed in the bottom of catch ditches. It should be covered with small broken rock or loose earth to keep falling rocks from bouncing or exploding.

6.5 Wire Mesh Blankets

Woven wire mesh can economically protect track from rocks up to 2 or 3 ft in size. It can be used either as a slope blanket or a catch net.

Blankets of wire mesh draped over rock surfaces as in Fig. 18 can restrain loose rocks and guide falling ones into the ditch below. Only a narrow ditch is needed. The same arrangement can be used on stony overburden slopes to prevent dislodged stones from rolling down. The mesh is slung from anchored cables at the top of slope, and ends a few feet above ditch level at the bottom.

Maintenance of the installation is straightforward. Before ditch clearing, the blanket is shaken or rolled part way up the slope to allow loose material to fall. Vegetation growing through the blanket will help to stabilize the slope, and grass seed and fertilizer are sometimes distributed. Some wire-mesh blankets which have been on slopes for 25 years have trees growing through them. Material for the blankets may be either gabion wire mesh or standard chain-link mesh. The weave of the gabion type wire will not unravel in case of local breakage.

6.6 Catch Nets and Fences

Wire mesh can also be effective in intercepting bouncing rocks up to 2 or 3 ft in size when mounted as a flexible *catch net* over the lower end of a steep gully. The mesh is hung from a cable anchored to sound rock on either side of the gully, as sketched in Part (8) of Fig. 17. Rocks hitting the net are caught and fall into the ditch.

A *catch fence* can be used similarly on the track side of the ditch or at the base of slope, with or without a shaped ditch, and located so that accumulated rocks can easily be removed. Various arrangements are shown in Parts (3) to (6) of Fig. 17. The wire mesh forming the fence is hung on a cable supported on posts as shown in Part (7) of the figure.

6.7 Catch Walls

Walls can be used to form a rigid barrier at the track to catch rolling or bouncing rocks up to a size of 5 or 6 ft, and at the same time increase the storage capacity of the ditch so that maintenance intervals can be extended. For maximum protection and storage, catch walls should be located on the track side of the ditch, at the same time leaving room for any snow clearing required. The wall must of course be a stable structure, with anchors to rock if necessary. In all installations, access should be left for maintenance equipment to clear out accumulated debris.

Various types of wall are suitable. Concrete walls can be precast in sections and installed as in Fig. 19 with the sections linked or keyed to resist overturning. Such a wall can be combined effectively with an enlarged catchment area formed by excavation behind it. Gabion walls can be built with hand labor and are flexible under rock impact. However, they lack the structural strength of concrete.

Rail walls are the most common type of protection used on many European railways. A typical installation is shown in Fig. 20. The posts are scrap rail set in concrete footings. Horizontal members are ties or scrap rails. The walls may be anchored back on the uphill side by cables to concrete pads or rock bolts, or braced as shown with rail struts on the downhill side.

6.8 Rock Sheds and Tunnels

These are the ultimate protection against rock falls when stabilization or other form of track protection are not effective or economical. All aspects of tunneling are extensively discussed in engineering literature.

The requirements of *rock sheds* are not as well known. They should have provision for a cover of 2 to 3 ft of loose sand to reduce the impact of falling rocks. As in the example in Fig. 21, cantilevered sheds can be used where support for piers on the outer side of track is inadequate, using heavy rock anchors into the upper slope for stability.

7. WARNING MEASURES

Warning methods were pioneered by North American railroads long ago to detect rocks in the vicinity of track and warn trains. The standard method in use is the AAR type of electric slide detector fence (AAR 1967) shown in Fig. 22, with horizontal wires spaced 8 to 10 inches apart between the poles. Along the most dangerous sections of track, patrols ahead of trains are also used. Two-man patrols give good capability for observation of all hazards as well as removal of small rocks from track, but involve substantial costs.

Of railways contacted in other countries, only two use the electric detector fence (see Table 1). On electrified European lines, the catenary power system is shut off automatically by large slides and, as has been mentioned, there is apparently little occasion to warn traffic against individual rocks.

Recent studies by CN confirm that the principle of electric warning fences is sound. However, it is also found that they give false alarms as much as 80 percent of the time (Railway Transport Committee 1973). The principle should therefore be applied in more efficient and economical ways. An example is to use a single electric wire, fastened around a broken rock or rock mass above the track, across a gully where large rocks roll down as in Fig. 23, or mounted on top of a protective wall or net. It can be anchored at both ends and linked to a warning system. It has advantages of good reliability, simplicity, ease of installation and maintenance, and no interference with snow-clearing operations.

At the present time CN is testing the effectiveness of geophones buried at intervals along the track shoulder to detect vibrations from falling rocks, but this work has not reached a stage where recommendations can be made.

8. ORGANIZATION OF WORK

8.1 Policy

Overall policy in combatting rock falls to increase the safety of a railway line should be to implement a consistent long-term improvement program with carefully selected priorities. It should be kept in mind that the size of an unstable area is not a good criterion of its danger, as any single rock can cause a derailment. Some of the remedies described, such as wire-mesh blankets, walls, fences and one-wire warning systems can safeguard small areas at low cost.

First emphasis should therefore be on securing the greatest number of individual locations where rock-fall hazards exist. Wherever possible, large problem areas should be divided into smaller component areas for priority or separate treatment. In this way benefits will be spread as far as possible and safety increased most rapidly.

After, say, 5 years of this approach at the start of a long-term program, the safety of many of the "small" locations will be assured and some of the larger ones protected, at least temporarily, by economical means. Attention should then gradually turn toward major improvements justified by traffic, such as extensive slope stabilization, tunnels, and rock sheds.

8.2 Annual Program and Priorities

The various steps suggested in an annual program and their purpose are listed in Table 2.

Factors which should be considered in deciding on the priority of sites for remedial work are:

- maintenance costs, including patrols required
- estimated costs of remedial work and benefits gained
- appraisal by specialists of degree of risk to track, taking into account the record of past events, measured rock movements and frequency of clearing rocks from vicinity
- accidents (although frequency of clearing rocks is a better indication of hazard)
- conditions downhill from the track, indicating how serious a derailment would be, and
- information from discussions with enginemen.

8.3 Choice of Treatment Methods

The recommended approach to analyzing a problem at a particular site and deciding on the most suitable method of treatment is shown schematically in Fig. 24. From the observed site conditions and application of engineering judgment, the most suitable method is chosen. The order of choice is based on the following facts and philosophy:

- *Stabilization methods* will reduce the frequency of rock falls. They are generally complex and expensive to install. However, as they do result in minimum maintenance costs and give a positive solution, they should be considered first at any location.
- *Protection methods* should receive attention next as offering a positive solution to a problem, often at reasonable first cost, but requiring continuing maintenance. They can be combined with warning methods.
- *Warning methods* will always be needed due to the broken condition of rock slopes, the topography and weather on rail lines in rugged terrain. However, they will become less appropriate in the course of a long-term remedial

program as stabilization and protection methods take effect and traffic density rises. Warning methods involve no reduction and sometimes an increase in maintenance costs, and have no effect on the source of danger.

8.4 Records

In any program to combat rock falls, continuing detailed records are required for good planning with proper priorities. Records which should be kept are listed in Table 3. For each troublesome location the maintenance, installations and measurements required should be recorded.

Photographs and measurements will help in evaluating rock and slope conditions and changes in them which affect track, and so aid in deciding on relative risks and types of remedial work required.

Selective measurements can show at what rate rock movements are taking place and detect any increase in that rate at a particular location which could indicate future trouble. There should be no attempt to use a pre-set amount of rock movement to set off an automatic warning. No one can tell just how far a rock mass can move before failing, and the only certain result of such a procedure is loss of confidence in the measurements.

There is a large choice of commercial instruments available for measuring rock movements (Highway Focus 1972) and specialist advice is recommended in organizing a measurement program. Movement of individual rocks near the track can be observed by applying a layer of shotcrete over cracks or using a mechanical extensometer. Measurement of microseisms to indicate rock stability is not generally advised as they reflect the condition of the deep rock mass and not its broken surface.

8.5 Staff

A great deal of work is needed to formulate and carry out a continuing rock-fall remedial program. Each site is different. There are no general ready-made solutions, and decisions must be worked out yard by yard along the right-of-way. People are required on a continuing basis.

An experienced and imaginative project engineer with supporting staff should be assigned full time to the work. An experienced engineering geologist should be available to help him in making detailed inspections and judgments on specific rock conditions, and in planning and supervising specialized work. Every highway department and more than half the railways contacted in the CN study had engineering geologists on staff for work on rock and soil problems.

While railway engineering staff must do the basic planning and supervision, consultants are essential for certain phases of the work:

- to assist with annual appraisal surveys
- to advise in detail on highly specialized work, and
- to keep in a position to represent railway interests in any legal proceedings.

Continuity of service of everyone connected with improving and maintaining track in mountain territory is important. The job is different in many respects from elsewhere and experience is a valuable asset.

8.6 Contract Work

Experience and up-to-date knowledge of equipment and techniques are most important for efficient rock work. At the same time, major revisions during the course of the work are often required for best results. For these reasons, tenders for rock work should be invited from contractors known to be experienced on a unit price or cost-plus-fixed-fee basis, rather than on a lump-sum basis.

8.7 Liaison with Others

The methods outlined for improving track safety from rock falls cannot be successful unless accepted and supported by all involved. Maintenance of way staff from engineers to section foremen should have opportunity to hear, ask questions and make suggestions about the program. In return, they should be asked to co-operate fully, particularly in the assembly of good records.

It is also important that enginemen on the line have a full explanation of what is being done. Opportunity should be given for questions and suggestions, and a continuing effort made to communicate with them. As an example, they should understand, if possible, how a protective installation will be safer for them at some locations than the warning fences they are used to seeing.

Open communication with all concerned will minimize resistance to progress.

References

A.A.R. (1967). Signal Requisites—Rock Fall and Slide Detection. Part 205, Signal Manual, Washington.

Amer. Concrete Inst. (1974). Use of Shotcrete for Underground Structural Support, Publication SP-45, Detroit.

Bureau of Public Roads (1966). Presplitting—A Controlled Blasting Technique for Rock Cuts. Dept. of Commerce, Washington.

Highway Focus (1972). Compilation of papers on Measurement and Instrumentation. Vol 4, No. 2 (June), Federal Hwy. Admin., Washington.

Patton, F. D. and D. U. Deere (1971). Geologic Factors Controlling Slope Stability in Open Pit Mines. First Intern'l. Conf. on Stability in Open Pit Mines, Proc. pp. 23–47, Vancouver.

Peckover, F. L. (1972). Treatment of Rock Falls on Railway Lines. Office of Chief Engineer, Canadian National Railways, Montreal.

Piteau, D. R. and F. L. Peckover (1975). Rock Slope Engineering. Chap. 9 of Transportation Research Board (1975).

Railway Transport Committee (1973). Report of Inquiry into Safety of Operation in the Mountain Territory of Canadian National and Canadian Pacific. Part 3, Ministry of Transport, Ottawa.

Ritchie, A. M. (1963). Evaluation of Rockfall and Its Control. Highway Research Board, Record 17, pp. 13–28, Washington.

Transportation Research Board (1975). Landslides: Analysis and Control. Washington. (In preparation)

TABLE 1

APPROACH TO ROCK FALL PROBLEMS TAKEN BY VARIOUS RAILWAYS (1972)

Country	Attitude and Results	Stabilization Measures	Protection Measures	Warning Systems
Norway	No compromise with safety. Single rock fall may justify permanent installation at that location. Regular maintenance program.	Annual scaling. Rock bolting, shotcreting, buttress walls under rocks.	Walls, tunnels, rock sheds, diversion ditches.	Electric fences linked to signal system.
Sweden	Relatively few rock problems.	Scaling, rock bolting, shotcreting.	Retaining walls, tunnels, rock sheds.	Electric fences found not satisfactory, vibration warning system planned
Switzerland	Regular contract maintenance of defences. Last accidents due to rocks: 1965 on BLS line, 1955 on RhB line.	Scaling, some shotcreting, buttresses, steel pins.	Strong emphasis. Original masonry and concrete walls, on slopes and at track, arches over gullies, buttresses, guiding walls, sheds and tunnels still maintained and supplemented. Rail walls, diversion ditches.	Patrols in some locations. No warning systems.

TABLE 1 (CONTINUED)

Country	Attitude and Results	Stabilization Measures	Protection Measures	Warning Systems.
West Germany	Thorough attention to maintenance. Accident due to rocks every 5 years, delays 1 or 2 per year.	Scaling each spring, wire mesh with rock anchors and shotcrete, rock bolting, steel pins. Anchored cast-in-concrete beams.	Rail and tie walls, woven cable walls, wire mesh draped on slopes, sheds and tunnels. Widening cuts.	No warning systems.
Austria	Regular maintenance program. Some delays each year due to rocks.	Scaling, rock bolting, shotcreting, buttress walls (some anchored), anchored concrete beams.	Rail and tie walls, woven cable walls (some anchored), wire mesh draped on slopes.	No warning systems.
Czecho-slovakia	About 10 delays per year due to rocks. Could not recall when last accident was.	Scaling, sprayed plaster or concrete buttresses, anchoring, rock bolting, various combinations.	Rail and tie walls, concrete walls.	No warning systems.
Japan		Drainage, grading, shotcreting.	Fences, retaining walls, rock sheds and tunnels.	Signal fences linked to dispatcher. Strain detection system being tried.
Canada - C.N.R. (1974)	Many rock problems. Remedial program diversified since 1972.	Annual scaling, rock bolting and dowels, some shotcreting.	Ditch shaping with catchment areas, retaining walls. Widened cuts using presplitting.	Electric fences linked to special signals. Patrols in some locations. Geophone system being tested.

TABLE 2

STEPS IN ANNUAL PROGRAM

ITEM	PURPOSE
Helicopter survey	To appraise inaccessible areas affecting track safety, get overall view of hazardous slopes
Ground survey (annual)	To appraise hazard at specific locations, decide on most likely solutions and need for detailed study
Ground survey (periodic)	To observe hazards and discuss them with M/W staff
Detailed study of specific sites	To appraise rock conditions and alternative treatments, decide on best solution
Decision on priorities	To recommend capital and maintenance program
Proposed budget	Preparation of details
Work program	Planning and supervising
Records and inspections	To appraise condition of slopes, M/W work required, and performance of installations
Maintenance of installations	To maintain effectiveness and dependability

TABLE 3

ESSENTIAL RECORDS

ITEM	DETAILS
Accidents	Standard form
Train delays	Time, number of hours, causes, etc.
Rocks on track	Time, exact location, size of average and largest rocks, volume of material, height and length over inner rail, source of material on slope (if known)
Removal of fallen material from track, ditches, behind walls	Date, exact location, size of average and largest rocks, volume of material, whether routine or emergency
Repairs to warning installations (fences)	Time, exact location, maintenance required, wires affected, size and final location of rocks
Stabilization and protection measures	As-constructed plans and inspection records including bolt tensions, etc.
Weather	Daily records of precipitation and temperature from local weather stations and recorders at selected locations
Photos	Air photos (standard, oblique, and close-range stereo) and ground photos
Rock movements	From distance-reading and direct-reading instruments
Costs	For all remedial and maintenance work

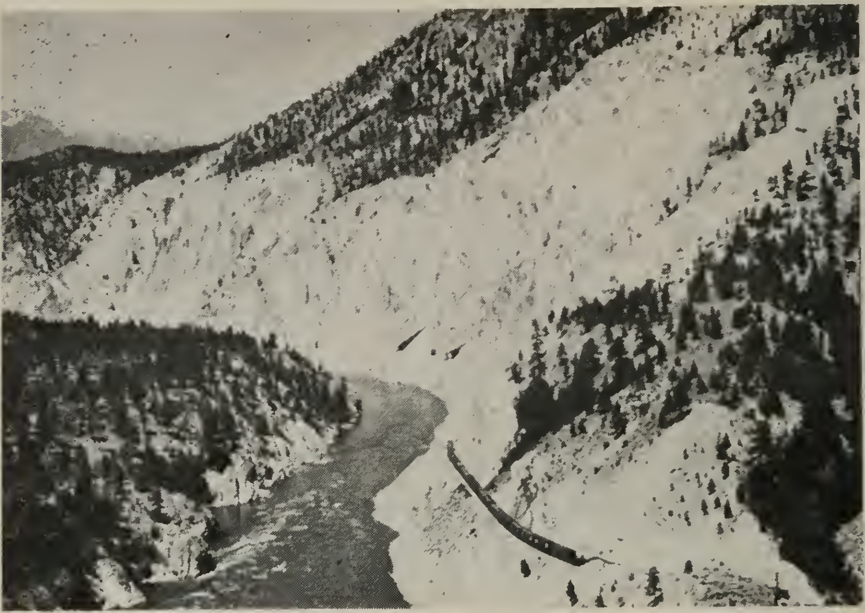


Fig. 1—The CN south main line in British Columbia passes through the White Canyon of the Thompson River.

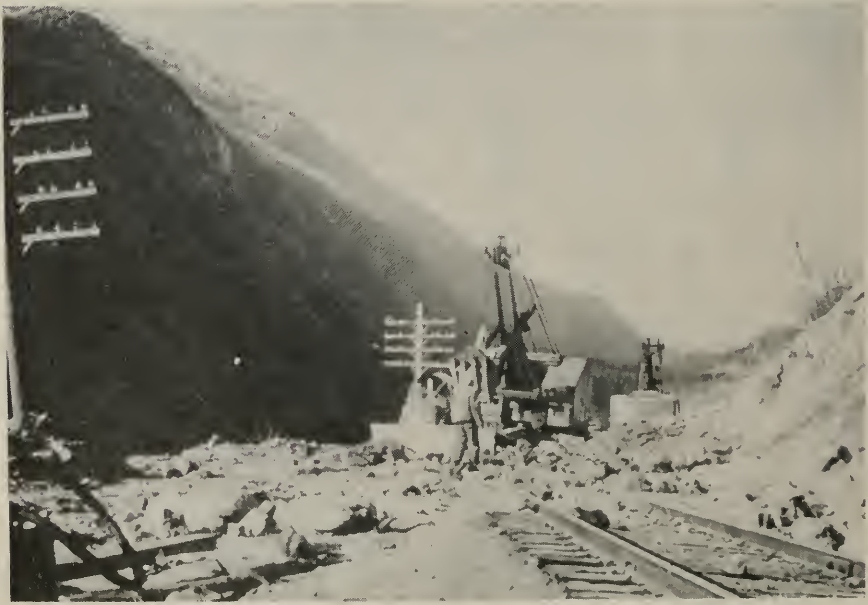


Fig. 2—A rock fall being cleared from track in the Fraser Canyon.

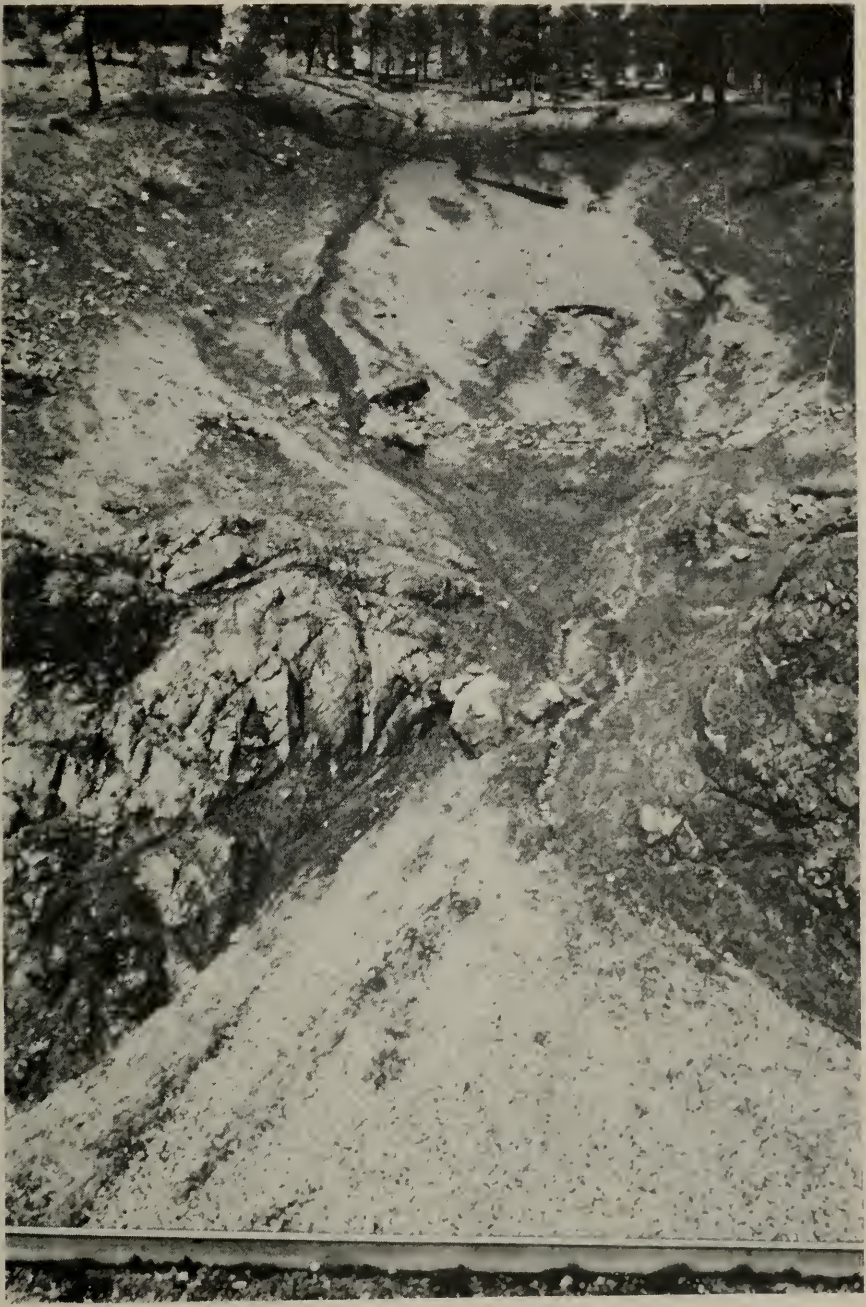


Fig. 3—Rock and earth debris deposited at base of gully.

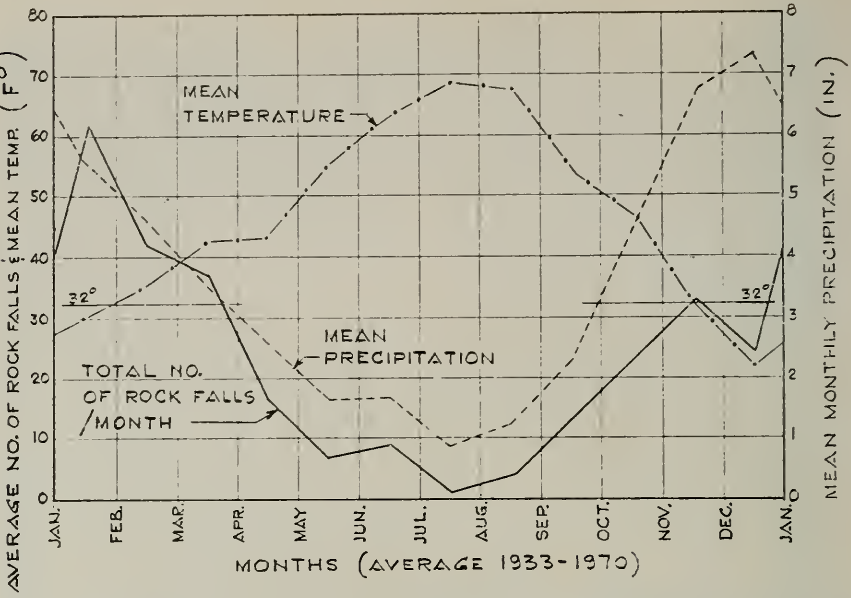


Fig. 4—Frequency of rock falls vs. temperature and precipitation in the Fraser Canyon, Yale Subdivision, CNR. (Peckover 1972)

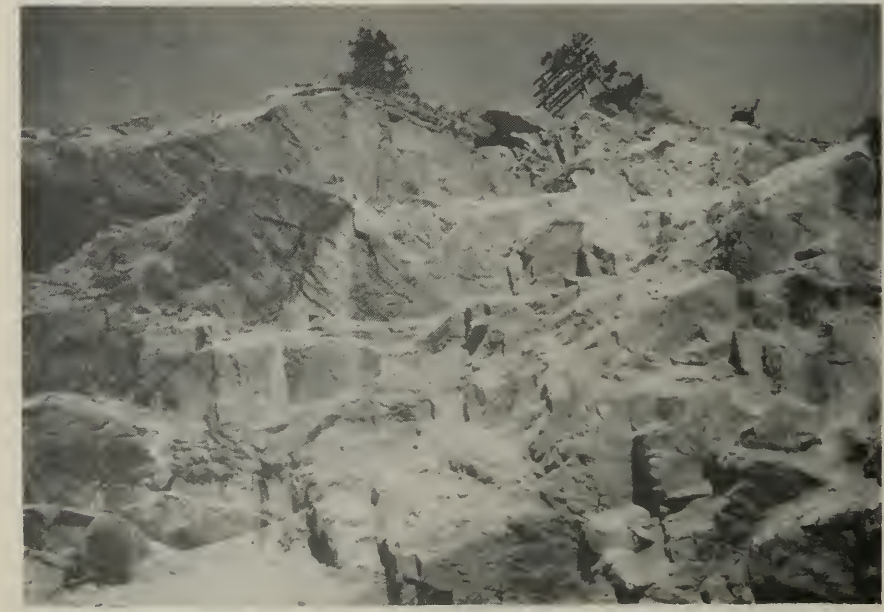


Fig. 5—Rock face, originally badly broken, after thorough scaling and shotcreting. (CNR)

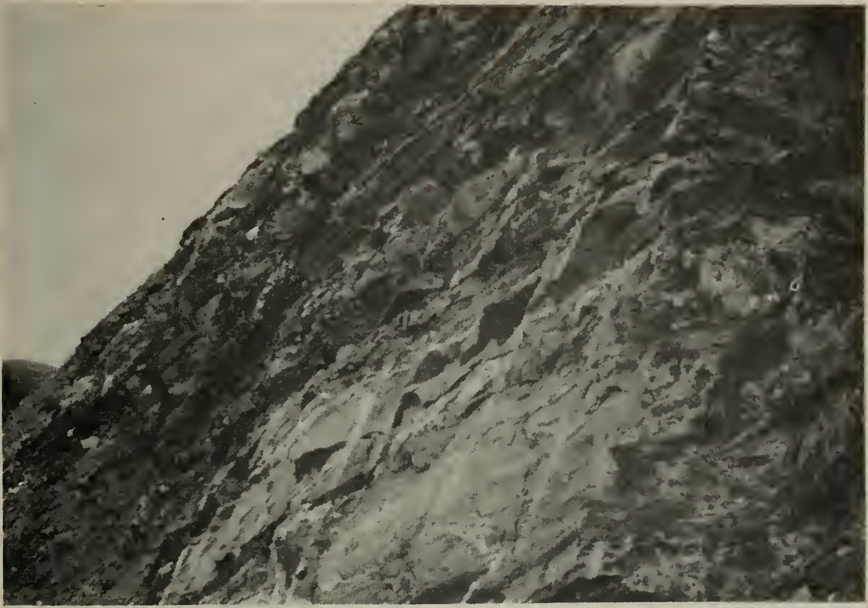


Fig. 6—Rock face excavated by presplit blasting on Highway I-70 in Colorado, showing lack of rock shattering.

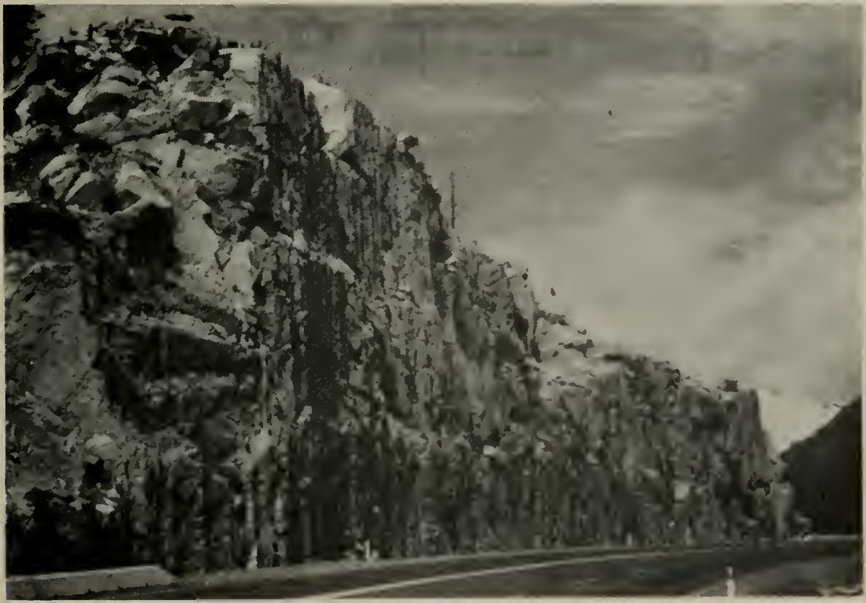


Fig. 7—Clean rock face obtained with presplit blasting on highway near Horseshoe Bay in British Columbia.

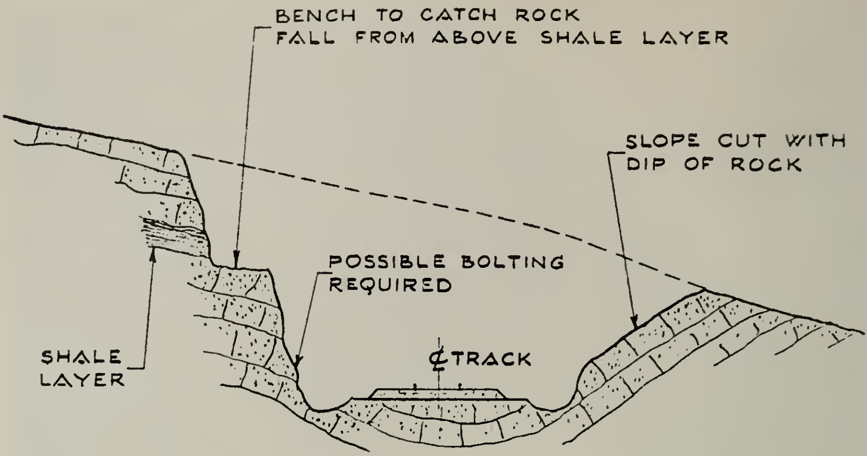


Fig. 8—Rock cut with designed slopes. (Peckover 1972)

Fig. 9—Gunite application made in 1954 on Austrian Federal Railways.

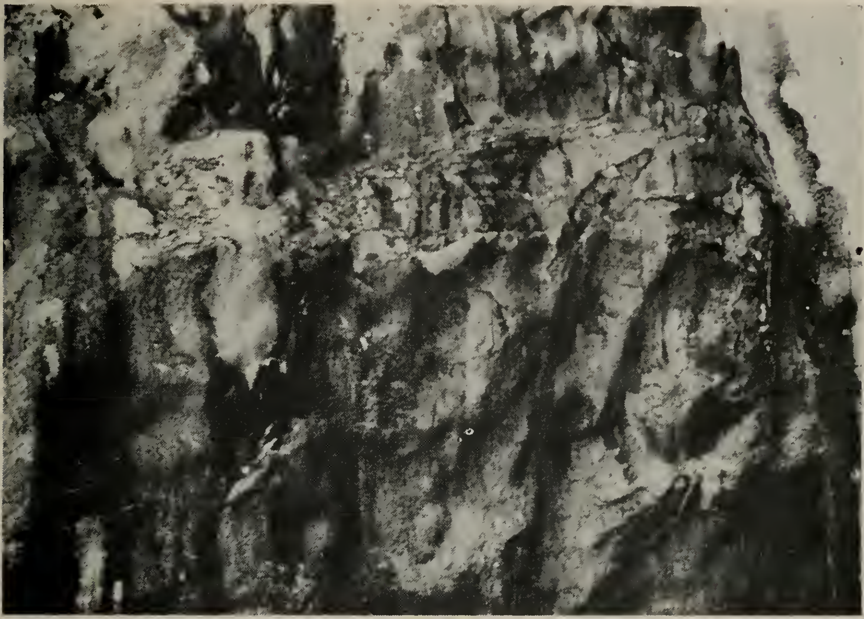


Fig. 10—Gunite application which has failed. Layer is too thin and no drainage was provided.

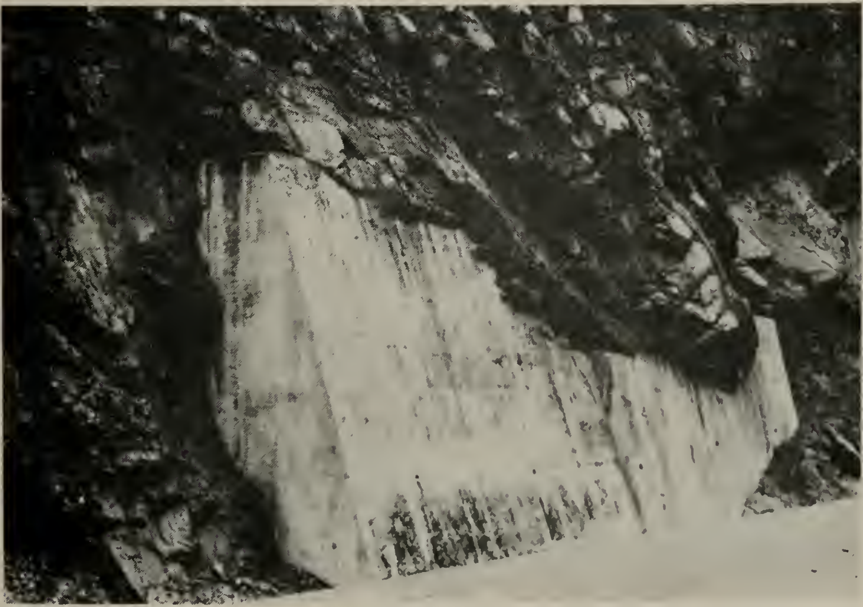


Fig. 11—Cast-in-place rock buttress on highway in Fraser Canyon.

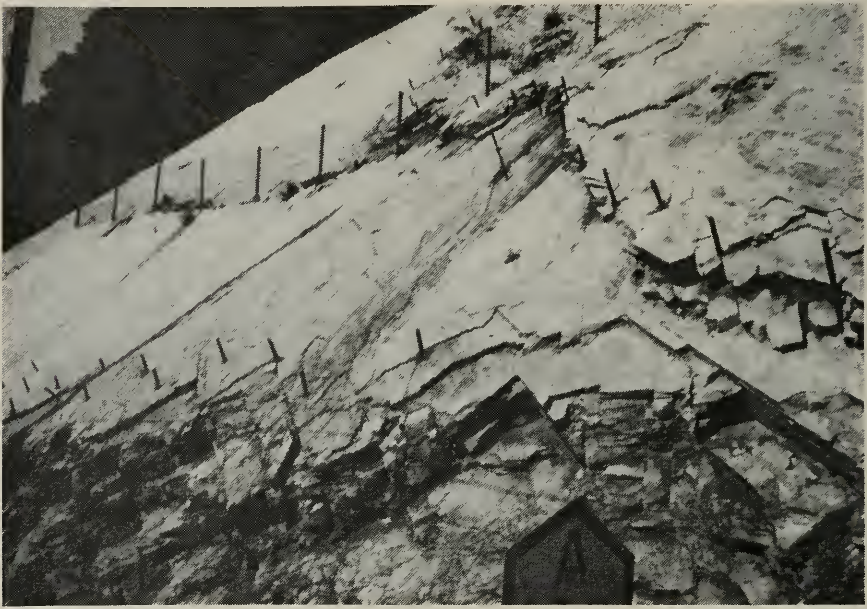


Fig. 12—Rock dowels to support dipping rock strata on rail line in Switzerland. Small catch fence is also provided. (Peckover 1972)

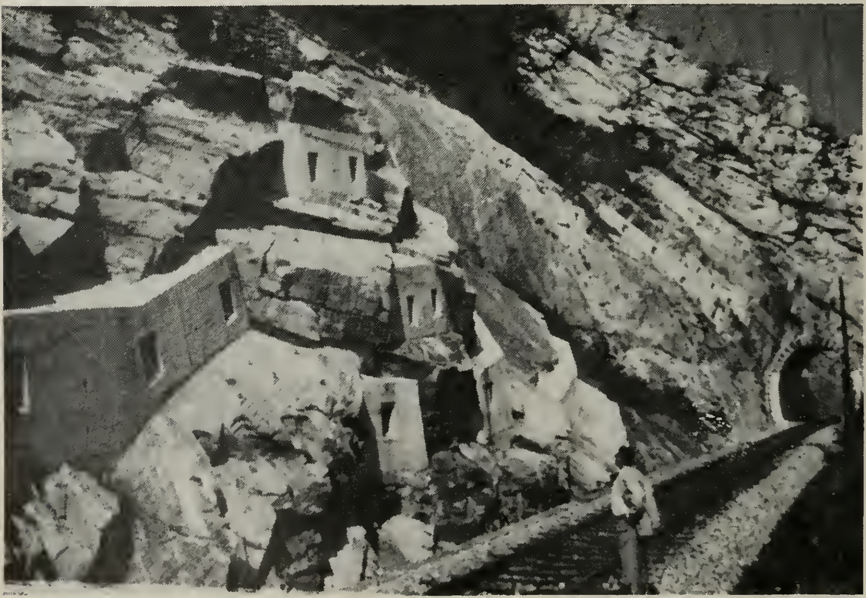
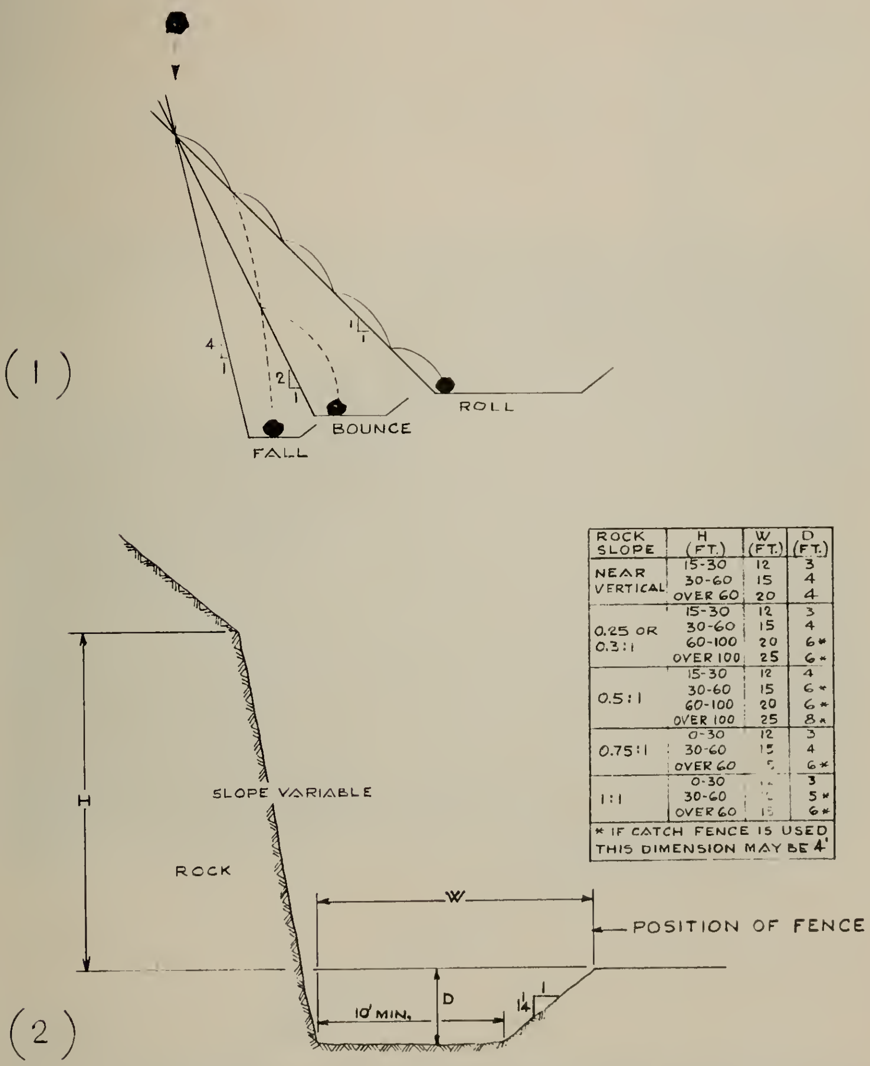


Fig. 13—Cast-in-place concrete beams with rock bolts, supporting sloping rock strata on main line of Austrian Federal Railways. (Peckover 1972)



ROCK SLOPE	H (FT.)	W (FT.)	D (FT.)
NEAR VERTICAL	15-30	12	3
	30-60	15	4
	OVER 60	20	4
0.25 OR 0.3:1	15-30	12	3
	30-60	15	4
	60-100	20	6*
	OVER 100	25	6*
0.5:1	15-30	12	4
	30-60	15	6*
	60-100	20	6*
	OVER 100	25	8*
0.75:1	0-30	12	3
	30-60	15	4
	OVER 60	5	6*
1:1	0-30	[illegible]	3
	30-60	[illegible]	5*
	OVER 60	15	6*

* IF CATCH FENCE IS USED THIS DIMENSION MAY BE 4'

Fig. 14—(1) Path of falling rock on various slopes. (2) Design of shaped ditches. (from Ritchie 1963)

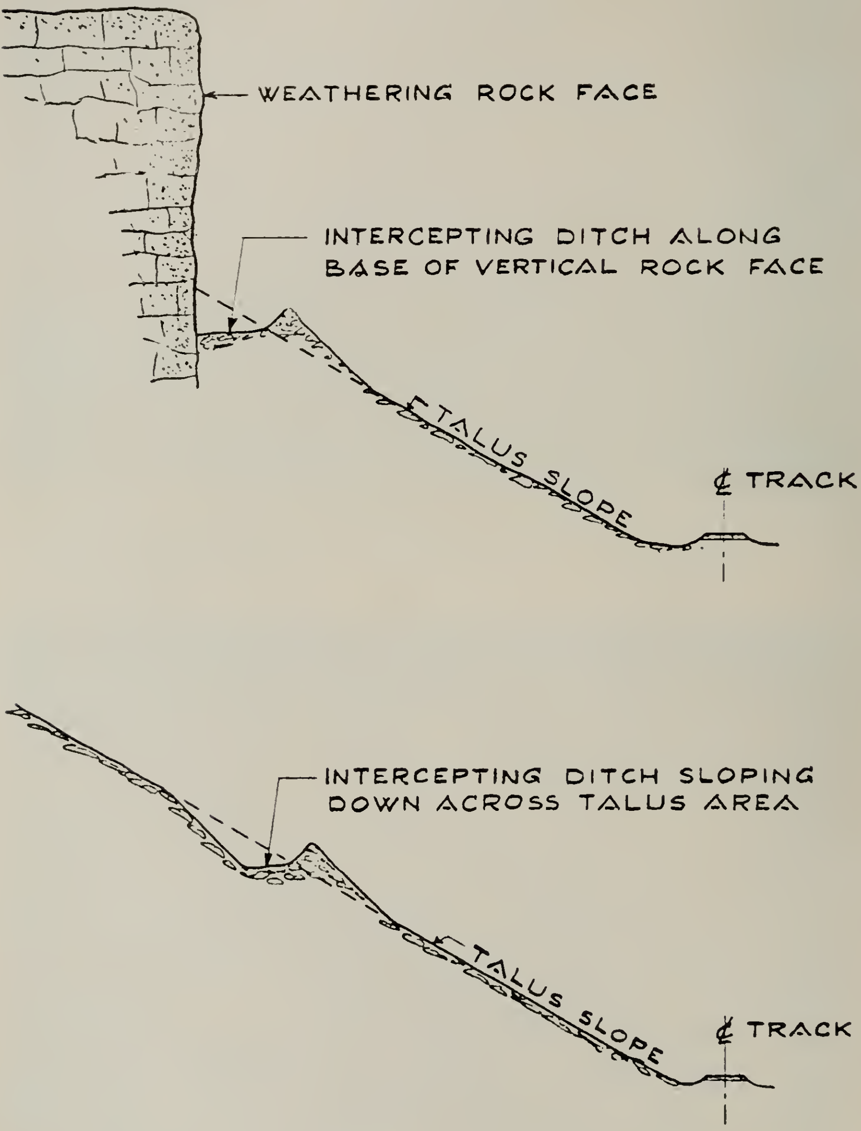

WEATHERING ROCK FACE
INTERCEPTING DITCH ALONG BASE OF VERTICAL ROCK FACE
TALUS SLOPE
℄ TRACK
INTERCEPTING DITCH SLOPING DOWN ACROSS TALUS AREA
TALUS SLOPE
℄ TRACK

Fig. 15—Intercepting ditches across talus slopes. (Peckover 1972)

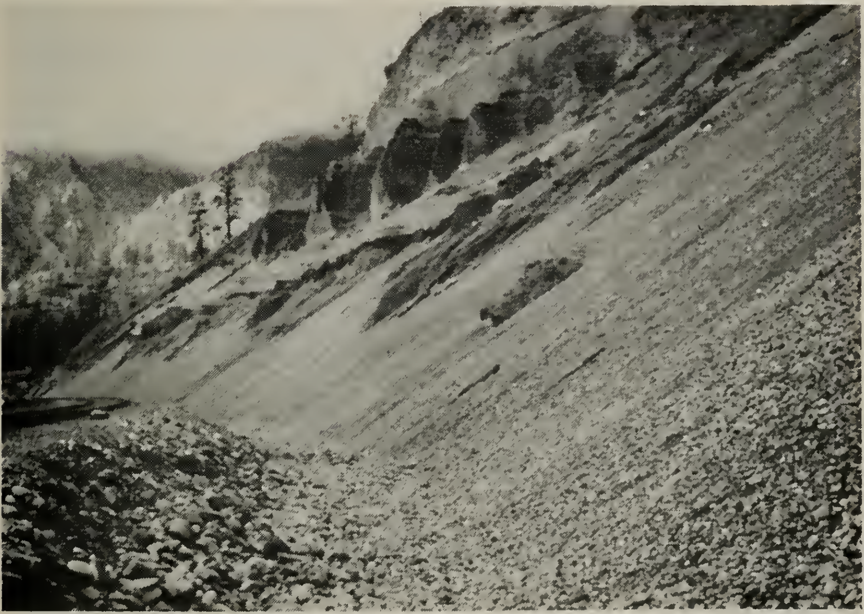


Fig. 16—Ditch shaped to retain stones rolling down from slope.

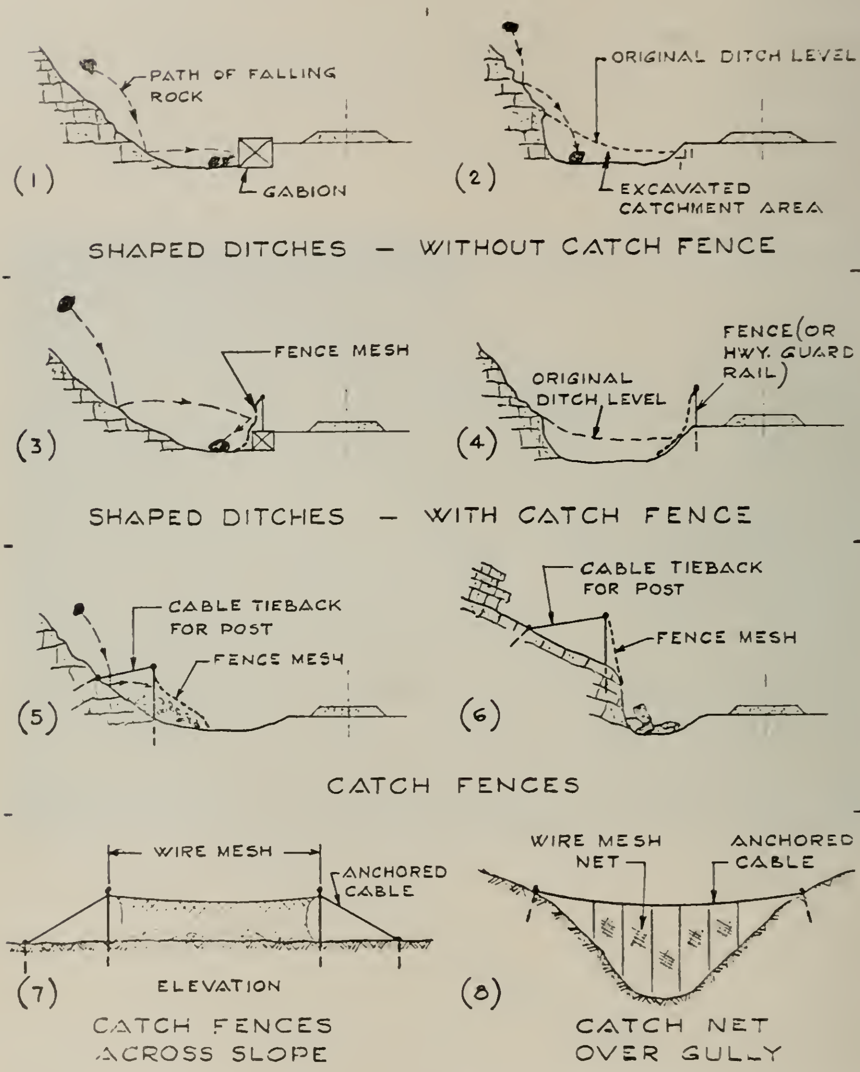


Fig. 17—Various arrangements of shaped ditches, wire-mesh catch fences and catch nets. (Peckover 1972)

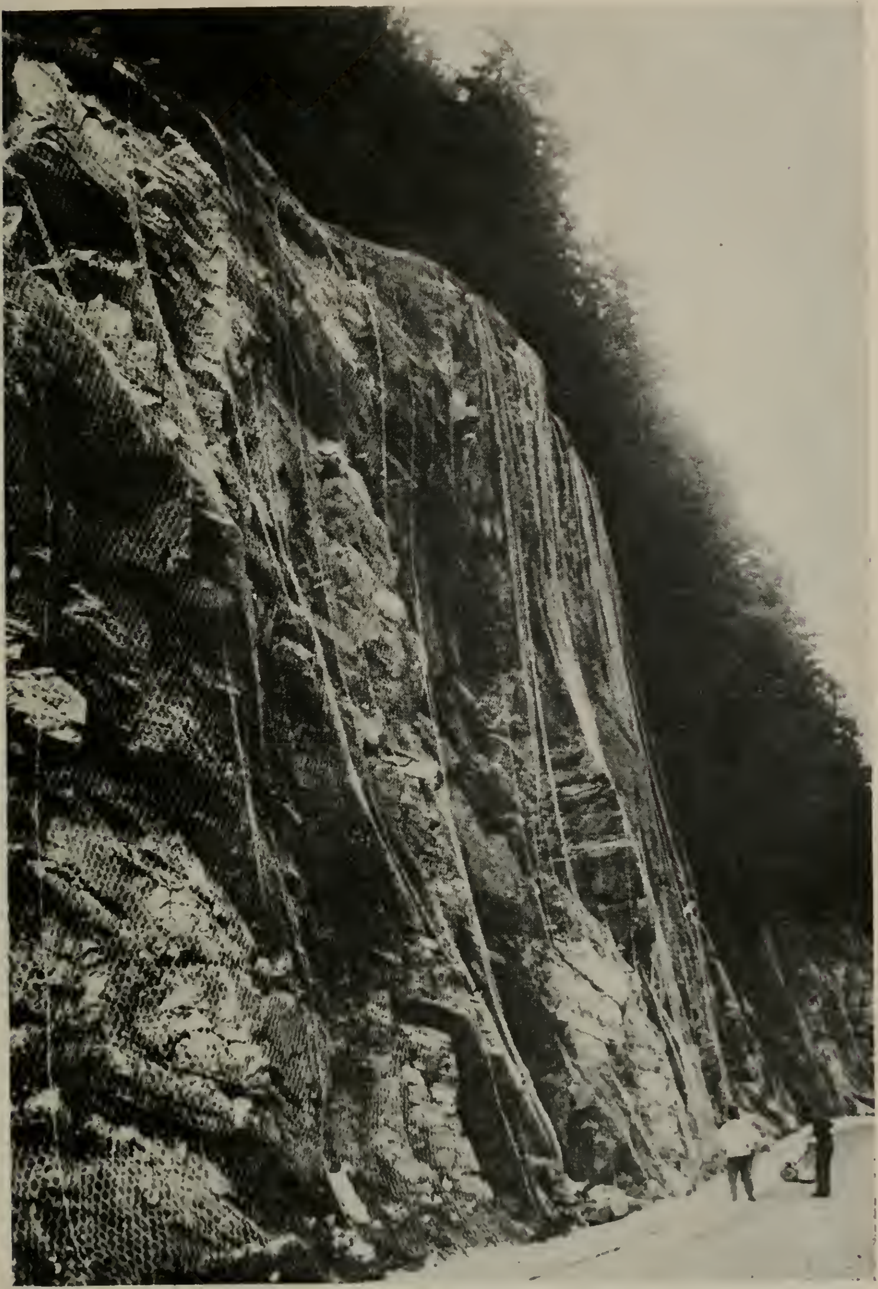


Fig. 18—Wire-mesh blanket draped on steep rock face before bolting to retain loose rocks. (Maccaferri Gabions of Canada Ltd.)

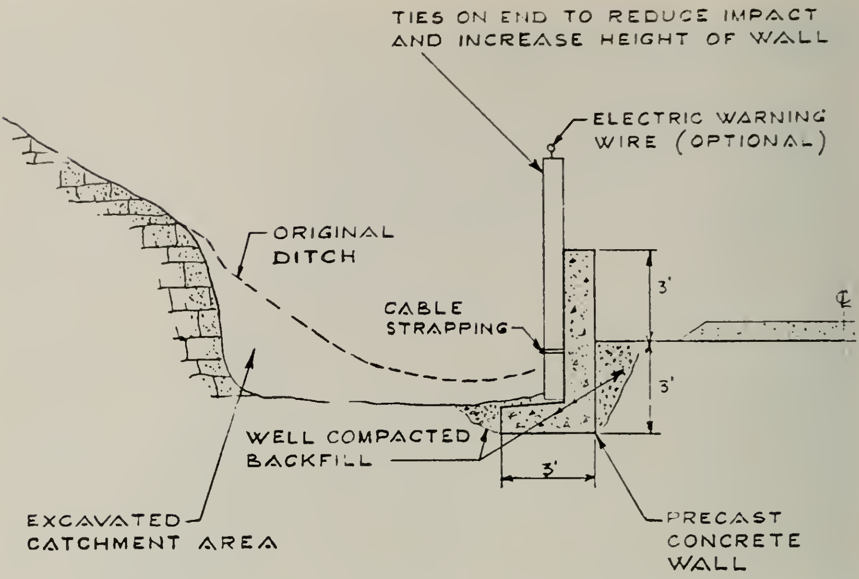


Fig. 19—Precast concrete wall for track protection. (Peckover 1972)

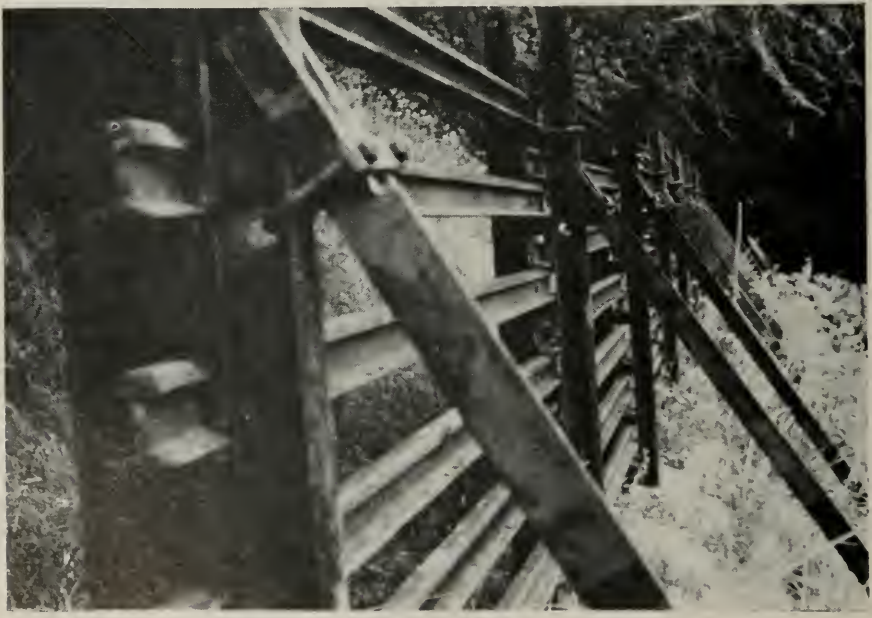


Fig. 20—Rail wall braced to guard against rolling rocks on BLS rail line in Switzerland.

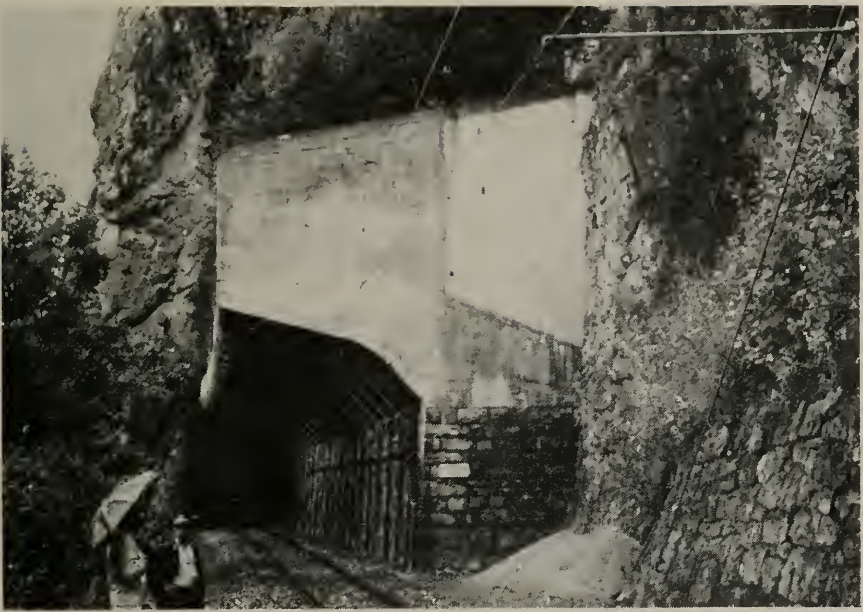


Fig. 21—Cantilevered rock shed anchored into upper rock slope on Swiss RhB rail line. (Peckover 1972)

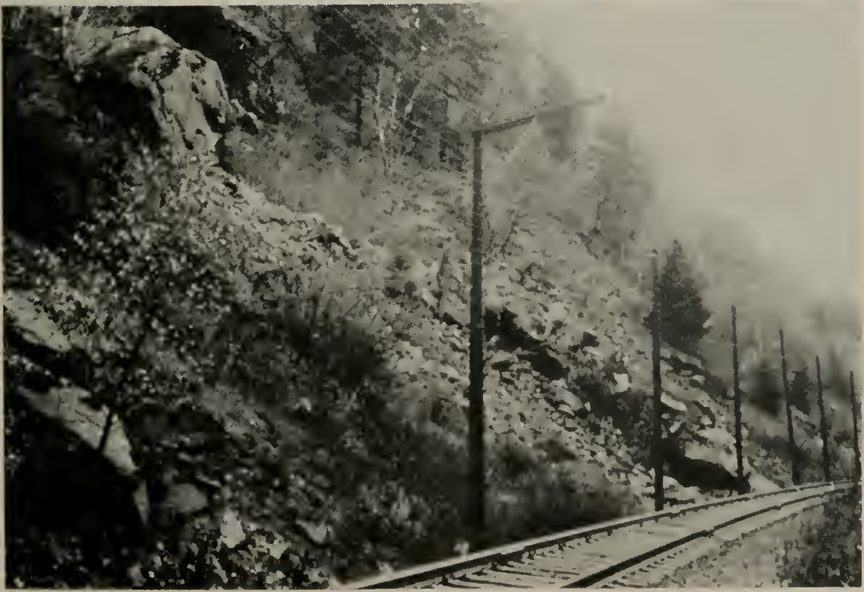


Fig. 22—Standard electric slide detector fence to warn of falling rocks.

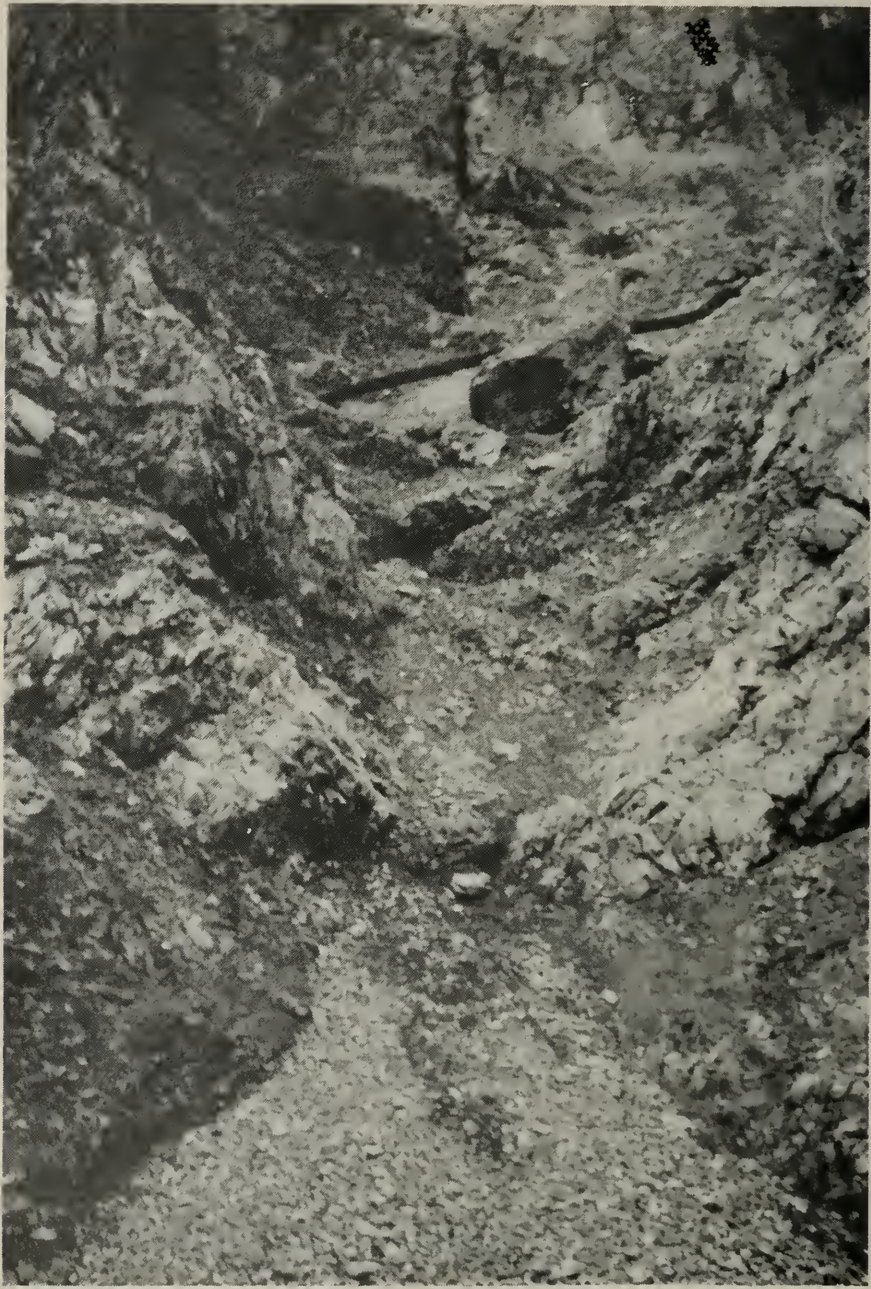


Fig. 23—Suitable location for single warning wire across gully to detect large rocks rolling down.

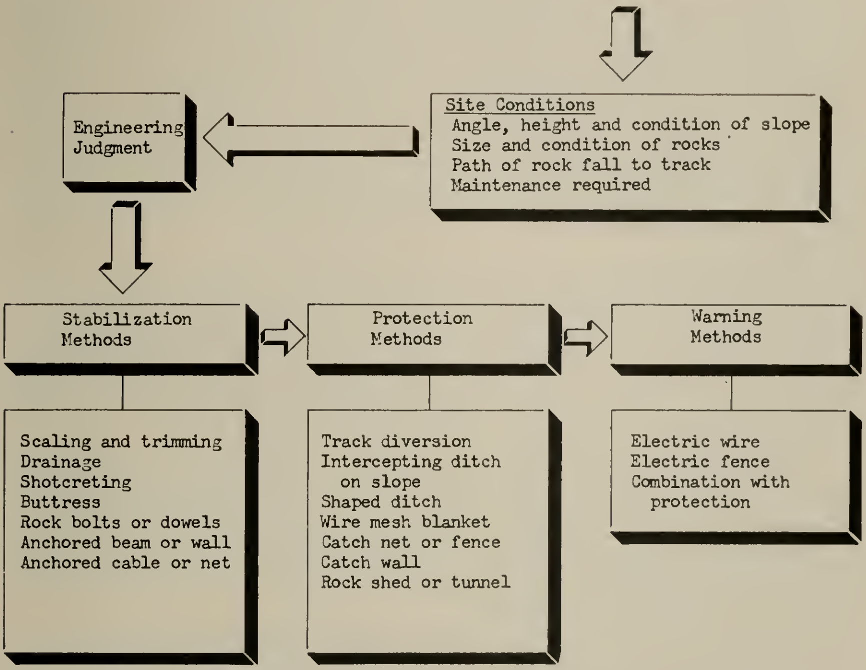


Fig. 24—Approach to choice of methods. (Peckover 1972)

Status Report on the National Rail-Highway Crossing Program—From a Railroad Viewpoint

76–653–3

By PATRICK J. McCUE
Executive Director, Highway-Rail Programs
Association of American Railroads

I certainly appreciate this opportunity to represent AREA Committee 9—Highways, in a discussion of the past year's achievements in the rail–highway crossing field. I'm honored to share this platform today with the executive director of the American Association of State Highway and Transportation Officials, Henrik Stafseth. Mr. Stafseth is going to discuss these same issues from the viewpoint of the state officials whom he represents. Therefore, if I direct some criticism at states which have failed to take the initiative in this program, it will be with the full knowledge that the states presently face difficulties in many critical areas and Mr. Stafseth is well qualified to defend or explain their approach to crossing improvement programs.

At last year's AREA Annual Technical Conference Bob Hunter, highway engineer in the Bureau of Railroads and Utilities, Federal Highway Administration, discussed provisions of the 1973 Federal-Aid Highway Act and FHWA Directives implementing that legislation. Mr. Hunter described the amounts of Federal funds authorized in the Act for rail–highway crossings and explained the types of projects that could be financed by the states with the new Federal funds.

The purpose of today's discussion is to review these new programs which are now about halfway through the three-year period covered by the 1973 Highway Act. It is certainly not too early to take a critical look at the areas where these new programs have succeeded or failed and to predict the direction they will take in the next year or two. We must also consider what changes, if any, should be recommended to the Congress in forthcoming legislation to improve or continue the crossing safety improvement programs.

At this point, I believe that a review of those sections of the 1973 Federal-Aid Highway Act pertinent to our discussion would be helpful. Title 2 of that legislation, which is called "The Highway Safety Act of 1973" established a major new national program for grade crossing safety improvements.

Section 203 of the Act authorized, for the first time, funding specifically and exclusively for improvements to rail–highway crossings on the Federal-Aid Highway System and required that at least one-half the funds spent under this Section be used for grade crossing warning devices. Funds authorized under Section 203 totaled $175 million for the three-year period beginning June 30, 1973.

Section 230 of the Act authorized, for the first time, funding for various types of safety improvements, including those at rail–highway crossings, for highways off the Federal-Aid System. Funds authorized under Section 230 totaled $250 million for the three-year period.

Funds authorized in these two sections could be used for the following types of crossing projects:

(1) Installation of standard signs and markings at all crossings;

(2) Installation of new train-activated warning devices;

Note: Discussion open until October 15, 1975.

(3) Upgrading of existing train-activated warning devices, including track circuit improvements and interconnection with highway traffic signals;

(4) Crossing illumination;

(5) Crossing surface improvements; and

(6) Grade separation.

The format of this broad new legislation clearly indicated that it was the intention of the Congress to establish a comprehensive, continuing national grade crossing safety improvement program. The outline for the program was contained in a 1972 Department of Transportation Report to Congress on Rail–Highway Safety. In that Report, the Secretary of Transportation established a goal of improving 30,000 dangerous crossings in this country over a ten-year period. The states were ordered to conduct and systematically maintain a survey of all highways to identify railroad crossings which may require separation, relocation, or warning devices and to establish and implement a schedule of projects for this purpose.

To assure compliance by the states, the Congress required that the Secretary of Transportation submit annually a detailed report of the states' activities in each of the new program areas, with recommendations for any necessary actions to remedy deficiencies revealed in the report. The Secretary has submitted his first annual report and we'll review that in a moment.

However, before we analyze activities of the states and the DOT, it seems only right that we should evaluate our own response to the new law, that is, actions taken by the railroad industry to bolster the new programs.

Because the railroads have no administrative responsibility for the new safety programs, we concentrated our efforts on collecting data and disseminating information to develop support for the states' programs. In addition to daily contacts with individuals and organizations at the local level, our activities included:

First, The publication and distribution of 40,000 brochures describing the 1973 Federal-Aid Highway Act and explaining local government involvement in the crossing safety program through the states;

Second, Assistance in the sponsorship of a National Conference on Railroad–Highway Crossing Safety at Colorado Springs in August, 1974. This fifth in a series of very successful conferences brought together more than 300 concerned professionals from the railroad industry, state highway and transportation departments, state regulatory agencies, Federal agencies, labor unions, and grade crossing equipment suppliers. Appropriately, the objective of the conference was, "To demonstrate how the partners in grade crossing improvement programs can best use new techniques and new funding in a cooperative effort to implement an effective grade crossing improvement program;"

Third, Our most significant effort was the National Rail–Highway Crossing Inventory and Numbering Project in which the railroad companies surveyed and posted identifying numbers at more than 400,000 crossings. About 100 railroads have now completed work on the inventory and forwarded the forms to state highway departments. We now estimate that by late Spring, 95% of all crossings will be numbered in the field

> and the forms forwarded to the states. However, unless processing of forms by the state highway departments is expedited, it will be at least December before all forms are on the new computer file at the Federal Railroad Administration. The FRA is combining the inventory data with accident data from the new Railroad Incident Report and will provide periodic summaries and listings to the states and railroads. Texas Transportation Institute has written a number of computer programs for analysis of the data and has offered the programs free of charge to the states and railroads. Last month, I advised all the railroad chief engineers that these programs are available from my office upon request. The Federal Highway Administration will provide them to any interested state.

The 1973 Federal-Aid Highway Act did not *require* completion of the National Grade Crossing Inventory and Numbering Project prior to obligation of the new Federal funds. However, it did require the states to use a reasonable, systematic method to identify crossings in need of improvement and to set priorities for their programs. Most states had some information on file which was useful for selecting projects, but the state files seldom included data on crossings off the state-maintained highway systems.

Consequently, in those states where the off-system improvement program has been implemented, the states have usually depended upon local government officials and/or the railroads to identify locations in need of improvements. Other states have used the lack of information as a reason for not implementing the program. It is therefore vitally important that the grade crossing inventory project be completed as soon as possible. Even though it may be December before the national file is 100% complete, we hope to have at least 80% of the data on file by June 30 and the states should have more than enough information to satisfy their programming requirements.

In regard to state activities under the new federal law, the "First Annual Report On Highway Safety Improvement Programs" by the Department of Transportation, which summarizes and evaluates state compliance with the 1973 Federal-Aid Highway Act, has been submitted to Congress. The Report covers fiscal year 1974 (July 1, 1973 to June 30, 1974).

In his letter of Transmittal, Secretary Brinegar stated, "The progress of these programs during their first year is encouraging even though a small amount of funds was obligated for the programs."

On the Federal-Aid Systems, where $25 million was authorized for 1974 the states initiated 87 projects which obligated a total of $2,025,420. Thirty-two states did not obligate funds in fiscal year 1974. Ohio programmed 24 projects which accounted for 39% of the Federal funds obligated for grade crossings.

Use of the funds was about evenly split between projects for signing and/or marking, and projects to install automatic gates or flashing lights.

The DOT showed great ambivalence in evaluating the states' performance. The report stated that "With few exceptions, the states are well organized to implement the provisions of the program. This was as expected because Federal-Aid funds for the elimination of hazards at railroad–highway crossings on the Federal-Aid Systems have been provided for 30 years." Notwithstanding this fact, the DOT pleaded that it was unable to fulfill its legal obligation to make recommendations to the Congress on improving the program because, ". . . substantial project data are not available from this first year of funding."

Section 230 of the 1973 Federal-Aid Highway Act authorized *$50 million* in 1974 for highway safety projects on non-Federal-Aid routes. Due to limited time and lack of information, only ten states were able to use any of these funds in fiscal year 1974. Seven of those states used their funds for surveys of hazards. Thus only three states actually initiated construction projects. Minnesota set up one very large statewide project to install and upgrade traffic signs, including signs and markings for railroad–highway grade crossings in almost every county; total cost—$2,272,720. Ohio initiated 24 projects for signs and markings at rail–highway crossings at a cost of $2,597,596. Wisconsin programmed 8 local projects at a cost of $441,620.

This portion of the Federal law also required each state to identify, not later than June 30, 1974, projects to be carried out with the new Federal funds. Thirteen states *did not submit* these schedules. The Department of Transportation concluded that the actual figures on projects implemented were misleading and that, as a matter of fact, "Overall progress in this initial phase has been good; even though a low number of projects were authorized the program is considered satisfactory."

The Secretary's satisfaction was not shared by the Federal Highway Administrator. During the first week of October 1974 the FHWA issued three Directives to the states establishing "Fiscal Year 1975 Program Emphasis Areas."

To quote one of the Directives, "FHWA's national emphasis for fiscal year 1975 includes a strong impetus for the highway safety construction programs contained in the Highway Safety Act of 1973. To affirm this emphasis, a goal has been set to obligate $250 million of Federal-Aid funds during fiscal year 1975." While the $250 million FHWA 1975 goal is an impressive figure in comparison to the states' expenditures in fiscal year 1974, it still represents only 53% of the amount authorized by Congress for these programs for fiscal year 1975. The Federal Highway Administration clearly does not expect the states to fully comply with the law but they do expect a reasonable effort.

At the same time these goals were set, the FHWA also initiated a monthly computer printout which identifies funds obligated by the states in each program area. As of December 31, 1974, one-half way through fiscal year 1975, the states had obligated $6,683,000 for rail–highway crossing improvements on the Federal-Aid System or about 9% of their 1975 authorization. The states have obligated $6,748,000 for safety improvements on non-Federal-Aid routes or about 4½% of their 1975 authorization. From the reports it is not possible to determine how much of the off-system money was used for grade crossing improvements.

These figures indicate that the FHWA emphasis has resulted in additional expenditures by the states for crossing projects. So even though the amounts are still low, the trend is up. Hopefully, President Ford's recent release of $2 billion of impounded highway funds will place the states in a much better position to fund the safety projects. Grade crossing projects can be accomplished by the states without the use of state matching funds, which are presently very scarce in most states, and the President identified safety projects as one of the three priorities for which the extra Federal funds could be used. Norbert Tiemann, the Federal Highway Administrator has stated that there is more than ample money available to fund all the projects which the states can obligate by June 30. Therefore, it is clearly in our interest to encourage the states to fund these projects now.

Conclusions

In conclusion, I want to pre-empt Mr. Stafseth by saying, in defense of the state highway departments, that the figures I quoted today do not represent *total* expenditures by the states for rail–highway programs. The states are spending considerable amounts from special state crossing funds and also from Federal funds other than the special categories which I discussed today. For example, in fiscal year 1974 the states partially financed more than 1000 signal installations.

Nevertheless, it is important to distinguish these different funding arrangements because many of the state grade crossing funds require significant contributions from the railroads, contributions which the Federal Highway Administration considers unfair and which cannot be required by the states when Federal funds are used.

I raise this point in closing because the DOT, in its 1975 proposals for Federal highway legislation, has recommended that the Congress abolish categorical funding programs such as the ones I described today which finance crossing improvements.

The DOT proposes that in the future, grade crossing funds should be combined with all other types of safety projects in one "Highway Safety Construction" category. Rail–highway grade separations would be specifically excluded from this funding. While the elimination of special categories would undoubtedly make life simpler for the state highway officials who presently must attempt to finance their programs from more than 30 special classes of funds, it would probably also permanently retard the development of any significant state grade crossing programs.

Finally, in summary I will simply say that despite some disappointments in the past year, the rail–highway crossing safety program *is* growing, *some* of the Federal money is being spent, the DOT's emphasis program and the President's release of $2 billion should significantly accelerate the states' obligation of funds, and the program stands a good chance of continuing and succeeding if support of the Congress, the railroads and the public does not waver.

Status Report on the National Rail-Highway Crossing Program—From a Highway Viewpoint

76–653–4

By **HENRIK E. STAFSETH**
Executive Director
American Association of State Highway and Transportation Officials

I much appreciate Pat McCue's opening remarks which could be interpreted as giving State Transportation Agencies "power of enactment" or legislation. Unfortunately or fortunately, whichever your view, this is not true.

I have come to your meeting with appreciation of not only your invitation, but also of the progress now being made by the railroads and the states in this joint venture in rail-highway crossing inventory and numbering program.

Before leaving Washington, I asked for a current status report on this program of mutual concern to members of both Associations. The material was provided in the main by the Federal Highway Administration, which is closely monitoring the progress of this program.

Pat McCue has given in his remarks the history of the origins of the program and the legislative mandates, and has added some additional comments which appear critical of the states. But here is a brief report, which I hope and intend as constructive to all our needs as partners in fact, as well as necessity.

The Federally-aided National Grade Crossing Inventory and Numbering Project officially started November 1, 1973. That was 16 months ago.

Before proceeding, I want to interject a comment that with many, if not most, new programs involving the marshalling of all forces of participating agencies and organizations on a national scale—it takes two or more years to begin to show results. This project is of massive proportions as it involves over 200,000 miles of track and some 412,000 crossings—an average of one every half mile.

As I said earlier, the railroad industry as a whole has and is now doing a fine job in carrying out its share of the work. Similarly, the states as a whole are doing a fine job in the 16 months since the official date of starting.

But let me present the status of the program as submitted to me:

The Federal Highway Administration first advised the states of the project by FHWA Notice dated December 12, 1972, which outlined the first phase as a pilot project involving five states, to be followed by a nationwide program. By March 23, 1973, FHWA Notice the states were provided more particulars. By July, 1973, all states had assigned personnel to the project. In brief, they were ready to go!

On August 2, 1973, FHWA Notice advised the states of the names of AAR representatives with whom to cooperate in their states, but noted that completion of the pilot project (in Connecticut, Virginia, Florida, Nevada and Colorado) was delayed.

But some of the rail industry had been at work. By September 1, 1974—(7 months ago or 10 months from November 1, 1973) this was the *status of progress:*

Note: Discussion open until October 15, 1975.

a. Inventories completed by railroads and forms forwarded to states for completion	67,249
b. Inventory forms completed by states and forwarded to Contractor Texas Transportation Institute (to establish magnetic file)	34,601
c. Backlog (forms being processed by states)	32,601

This indicates that the states were completing their work—to pinpoint the location of each crossing on highway systems, by functional road classification, and adding the estimates of ADT and the percent of tracks—at about 50% of the initial *volume* submitted.

But on September 11, 1974, the Federal Highway Administration wrote the Federal Railroad Administration (copy to McCue, AAR) calling attention to the slow progress of work by some states and railroads as reported in the August 15 status survey. The report stated that appropriate steps had been taken to increase productivity in those state agencies where progress appeared to be slow, and asking that AAR take similar action to improve production by railroad companies that were also slow progress.

Apparently, this strong report and appeal by the Federal Highway Administration and the states had some effect. Six months later—by this month, March 14, 1975—this is the current status of the work:

a. Inventories completed by railroads and forms forwarded to states for completion	272,826
b. Inventory forms completed by states and forwarded to T.T.I.	192,705
c. Backlog (forms being processed by states)	79,119

These comparative figures indicate that states as a whole are geared up to handling the work load being submitted by the railroads. To make this statement a bit more apparent—here are the latest figures available in a bite-size quantity. For the first two weeks of this month—March 1 to the 14th—the railroads submitted 12,827 inventory forms, and the states completed and processed 11,658, or a rate of 90% of those submitted.

As of March 14th, again 26 states have a backlog of less than 500 forms and 9, including the 5 pilot study states, have no backlog at all. In brief, 35 of the 52 states or jurisdictions involved have virtually completed all forms submitted to them —not bad when you think about it, and I am sure progress will improve with cooperation from all of us.

It is the considered view of FHWA that any state having a backlog of 2,000 or 3,000 forms does not pose a problem in meeting the June 15, 1975 deadline, *providing* they continue to work at a consistent and acceptable pace, and provide additional staff, if necessary, when railroads have completed their inventory work in the state and submitted completed forms to the state agency. (With two men at work, it should take only three weeks.)

All states are working to make this joint program a success. Some perhaps better than others. Some states and railroads perhaps thought it would never get started. I am reminded here of a similar situation in 1954 and 1955 when some folks in the states thought the Interstate Highway Program of 1956 would never come to pass. It did—and so has this program—and some have to play catch-up!

We expect, that out of 52 state highway and transportation departments participating, only seven may have potential problems in meeting the target date, providing all forms are submitted by the railroad industry with sufficient lead time prior to June 15, 1975.

Now I mention these facts because it demonstrates that both associations have problems. Some states obviously are going to have problems in meeting the deadline. Where they can do something to improve their operation, I am sure they will do so. I have recently alerted them to the need to review their operations with regard to progress in meeting the deadline. But state action alone is not enough. It is a joint effort, and even today some small railroads have not received (as of March 18) from AAR introductory materials in regard to the study, as well as number boards, inventory forms and manuals. This may be, in part, because no one knew where they were! Through cooperative action of the state highway departments, names and addresses of many railroads are being located and documented for the first time to provide an accurate list of all railroads in the United States. So now we all will know!

Now I want to go beyond the rail/highway crossing inventory and discuss briefly what comes after—the implementation of Section 203 of the Federal Aid Highway Act of 1973 regarding the rail/highway crossing safety program, including the proviso that one-half of the authorized funds are to be spent for safety devices.

Since Pat McCue has commented on the speech last year before this audience by Bob Hunter, of the Railroads and Utilities Division of FHWA, I checked out what Bob had to say, and I quote from his talk:

"There is one further matter that is of utmost concern, that is, the ability of the Federal, state and local governments, and particularly the railroad industry and equipment suppliers, to respond to the promise of this (1973) legislation and complete the installation of grade crossing warning devices under an accelerated program. We have been watching the current accumulation of projects for the installation of grade crossing warning devices with Federal-aid funds which are in the pipeline. These are projects for which funds have been obligated, and the work has been authorized but not yet completed. By our latest count there are over 700 projects in this backlogged status involving a total of $18 million. Well over 100 of these projects are in one state which has accelerated its grade crossing improvement program over the last two or three years. What is going to happen if and when other states accelerate their programs in a similar manner?

"When this occurs—when a large number of projects are caught in this backlogged status—funds are tied up but no safety benefit is being returned. This could result in funds being directed to other types of improvements. The realization of the promise of this legislation hinges on whether the warning devices can be installed in a timely manner."

So let's talk about progress in getting the $175 million of Section 203 rail/highway funds available for obligations by July 1, 1978, to work.

Up to June 30, 1974, a total of $4.3 million had been obligated for warning devices. By February 28, 1975 this had increased to a total of $13.3 million or a rate of $1 million (plus) a month. With only 39 months remaining, this rate of obligations will have to be drastically improved or Bob Hunter's warning of a year ago may come to pass, and these funds directed elsewhere.

Even more significant is that of the $13.3 million obligated, only $88,000 worth of work has been completed by the railroads.

The concern has been expressed, therefore, as to the railroads' ability to get the signalization of crossings work done within the time required. At least it is hoped that as the railroads complete their inventories they are, at least, installing crossbucks in accord with the MUTCD (Manual on Uniform Traffic Control Devices).

On February 11, 1975, President Ford released $2 billion of highway trust funds for obligations this fiscal year (1975).

By March 10, 1975 notice, the Federal Highway Administration announced that railroad-highway grade crossing safety improvements undertaken by railroad force account would be eligible for use of these funds provided the railroads can establish to the satisfaction of the state and division engineer that (1) major items of warning device material, if not available from stock, will be ordered from material suppliers within 45 days (after obligation), and (2) upon availability of the materials, the actual installation work will proceed expeditiously.

In reply to AAR President Ailes' telegram of February 14 to the FHWA asking for clarification and advice on use of those new funds by the railroads, Harry Lindberg, FHWA associate administrator for engineering and operations, provided the March 10 notice and replied by letter of last week (March 17, 1975) saying in part, and I quote:

"You asked what actions the railroads can take to expedite the completion of plans and agreements, the ordering of materials and the scheduling of work. We believe there are several such actions which could and should be taken. These include, (1) standardization of designs and their application, as needed, to reduce the amount of time consuming case-by-case design work required, (2) use of master agreements between states and railroads which cover standard agreement provisions and reduce delays in advancing individual projects, (3) review of internal company procedures to speed the flow of paperwork for procurement of materials, approval of agreements, and submission of bills, (4) organizational modifications to assign a single individual overall responsibility for grade crossing program of a company and authority to act across departmental lines, (5) review of the adequacy of the available labor force within individual companies and, if required, either contract for design and installation work or assign additional company personnel to such work, and (6) greater direct involvement with the other involved parties, particularly states, such as through periodic meetings.

"We appreciate the interest of the railroad industry and look forward to a cooperative effort in accelerating the construction of needed grade crossing improvements. Sincerely yours, /s/ H. A. Lindberg."

So there is the current picture as viewed across the board. Some good features, some not so good. In regard to the inventory phase of the program, I believe everyone—railroads and the state highway departments—are generally doing a "helluva" good job. We have our problems but they are small in comparison to the size and extent of the inventory. Needless to say, but deserving of saying, the work of the railroads in this joint effort made the inventory possible in the time allotted.

As I mentioned early in these remarks, it takes time to marshall all forces to get a program of such dimensions off the ground. It has taken, for example, four years from 1970 to the present to get Action Plans, including the preparation of guidelines, developed and approved in all 53 states and jurisdictions. These are concerned with procedures and organizational arrangements to be used to achieve full consideration of social, economic and environmental effects in the development of Federal-Aid highway projects, as mandated by Congress.

The TOPICS program took about a year to get off zero baseline and about four years to really get into full swing in obligating funds.

But, though the inventory phase fits a pattern, and there is some precedent in past performances to exceed an average of two years, we just do not have in this rail-highway crossing safety program any leeway in getting funds obligated and work performed.

The $2 billion of highway funds released by President Ford on February 11 had a primary objective of generating employment. The early elimination of high-hazard rail-highway crossings, and the signing, marking and/or signalization of all crossings is concerned with saving human lives, and that alone should give the program priority in our efforts.

Whatever the objectives—saving lives, reduction or elimination of physical and financial losses, increasing employment, both direct and through the "ripple effect" on suppliers of materials, or permitting improvement of rail and highway operations—they are worth the effort and the costs.

So now highways and rails are joined in common cause. Let's make sure that individually and jointly—cooperatively—we set a new precedent in putting the money to work in record time.

Let's high-ball this program!

Activity Relative to Flood Plains and Potential Effect on Railroad Installations

76–653–5

By D. S. BECHLY
Assistant Chief Engineer Structures
Illinois Central Gulf Railroad

On December 31, 1973 the President of the United States signed into law the Flood Disaster Protection Act of 1973. This Act substantially expands the National Flood Insurance Program and was passed in order to provide better protection to the public and to reduce annual disaster assistance outlays through the increased availability of flood insurance. This Act addresses three key areas: insurance, flood plain management and local community consultation and appeals procedures.

One requirement of the Act is that flood insurance, if available, must be provided for projects in identified flood-prone areas as a condition of Federal assistance. More specifically, communities having identifiable flood-prone areas are required to participate in the flood insurance program by July 1, 1975, or else they will become ineligible for Federally-related financing for projects that would be located in such areas. The term "Federally-related" financing includes almost any type of financing that is available to the housing and small business construction fields, such as, for example, obtaining a loan through a Federally-insured bank or savings and loan association. As a result, universal participation becomes virtually essential.

To achieve participation in the Flood Insurance Program, it is mandatory that the community adopts and enforces adequate and appropriate land use and control measures to reduce the probability of losses resulting from floods. It is because of these land use and control measure requirements that the transportation industry must become involved in what is essentially a program designed for the housing and urban development field. Last summer, at the first meeting of a special committee on rail transport activities of the Transportation Research Board, several railroad members raised serious concern about the impact on the railroads of state legislation relating to participation in the Federal Flood Insurance Program. Construction or modification of transportation facilities in flood plains seems threatened by such legislation, and it appeared that serious problems might be faced in the next few years.

Further investigation revealed that the approach to flood plain legislation has not been uniform from state to state. Some states have already acted, while others are in various stages of action. Some states appear to be including environmental factors as well as insurance factors in their legislation. As a result of these developments, a series of discussions were held by the Transportation Research Board and it was the consensus that this new and, to some extent, unrecognized problem should be brought to the attention of all members of the transportation industry. One result of this was the presentation by a panel on the subject at the Transportation Research Board's annual meeting held in Washington, D. C. last January. Another is my appearance on this platform today.

Note: Discussion open until October 15, 1975.

In the remarks I am about to make, I would like to bring to you some thoughts, based upon my experience, as to the impact that proposed flood-plain regulation may have upon the railroad segment of the transportation industry. In making these remarks I am speaking as an engineering officer of the Illinois Central Gulf Railroad and my data base, so to speak, is confined to the possible impact on that particular railroad. However, as it is one of the principal railroads of the country and operates throughout the length of the Mississippi River Valley, I would believe that these remarks would be typical for the railroad industry.

The purpose of the presentation this afternoon is to attempt to make you aware of the topic of flood-plain regulation. The widespread formulization of such regulation is an ongoing thing, and most of us in the railroad industry have not yet had to come to grips with it. As I have mentioned, the current concept was developed primarily in connection with the underwriting of Flood Protection Insurance Programs which, in my understanding, have been developed primarily for the housing industry. Nevertheless, the present and forthcoming regulations will definitely affect the railroads of the country. This effect will not necessarily be bad, but it could be a troublesome problem if we do not all become aware of flood-plain regulations and recognize our involvement with them.

The railroads of the United States of America were built, to the greater extent, during the middle and latter parts of the 19th Century. When their alignments were selected, those pioneers attempted to find the most economical route between two points and quite often followed rivers and their valleys to do this. This provided a route with the minimum rise and fall particularly necessary for the low-powered steam locomotives of those days. But where did this method of location place the railroads? In flood plains! And not just crossing the flood plains, but running longitudinally through them from end to end. Naturally, any regulation of flood plains must have an effect on the railroads. These regulations will not, of course, force the railroads from their present location, because I believe all of them will permit continuance of existing usage. It is in the acts of maintenance, reconstruction, improvement and new construction that their impact will come.

One might question whether the railroads are doing any new construction, but you all know that they are—generally not in spectacular new long through routes, but in small segments here and there of a half mile to five miles each; to serve an industry, reach a mine, improve alignment or reduce a grade. There are also new railroad facilities constantly being constructed, ranging from the spectacular multi-million dollar automatic freight car classification yards to smaller storage yards, sidings, repair tracks or other facilities that may be required to keep a railroad running. We have been involved in a flood-plain encroachment in one such activity; namely, a study for a possible new classification yard. In this instance, the solution required the lateral shifting of the yard's location to move it out of the flood plain. The effect of this on the cost of the project was not determined, and there were, undoubtedly, both plus and minus cost factors. The important point to be noted is early recognition of the infringement, so that adjustments in the plan will not be required at a later date if the project should go forward. While the change was readily accomplished in this case, it is easy to see how certain types of proposed construction along or across a flood plain could be drastically affected, or even made impossible, by some of the types of regulation that have been enacted or are being proposed. For example, a fill and a small bridge for a track to serve an industrial spur could be constructed across a minor flood plain and probably so built that they would resist the occasional flood of consequence even though partially damming the stream and causing the water elevation on the upstream side of the embankment to be higher than it would have been if the embankment had not been built. Most flood-plain regulations would now prohibit such construction and require that enough of the plain be bridged with spans of sufficient length to prevent the impoundment of any water or reduction of its velocity. This could be economically unfeasible and the spur, and possibly the industry it was to serve, would not be built. Whether this is good or bad depends upon your point of view, and also on whether or not the regulations have been properly administered. If, by administration of sound regulations, a railroad has been prevented from constructing a line that would be both hazardous to itself and to the public, this is, undoubtedly, good. If, on the other hand, arbitrary administration of a poorly developed regulation prohibits construction that would not, in fact, have adversely affected either the owner or the public, this is not good. The agencies with whom I have discussed the problem indicate their intention to recognize the practical economic needs of all concerned—the owner, the business community and the public—when considering the environmental and philosophical aspects of each case in order to not unnecessarily restrict the growth of the community.

As an engineering and maintenance of way officer of a railroad, with my primary responsibility being for its bridges and buildings, I am personally more concerned with the effects of flood-plain regulation on the maintenance of our existing facilities. The regulations generally indicate that maintenance of existing facilities in flood plains will be permitted and that permits to perform routine maintenance work will not be required. This obviously includes everything from surfacing the track, replacing cross ties or repairing grade crossings to painting bridges and buildings, repairing or replacing individual bridge members and oiling or greasing the machinery of a movable bridge. Where, however, does routine maintenance stop and some type of construction that requires a permit, start? For example, ditching, widening or raising an embankment, cutting brush and weeds, replacing riprap around ends of bridges to prevent scour, re-driving individual bents of timber trestles and numerous similar items. To the railroader these are all ordinary maintenance operations and have historically been performed year in and year out without any thought of outside permission. Remembering that a large percentage of many railroads' mileage lies within flood plains, will this continue to be the case?

Then take the instance of reconstruction of facilities—the additions and betterments, or capital account work such as the replacement of an existing bridge. Here we probably enter into a field where permits will be required. Of course, they may already be required in some states for certain types of streams, but it appears to me that the flood-plain regulation will broaden this concept widely so that it will include virtually every bridge, trestle or culvert replacement. This will require time, patience and paperwork. To obtain the time—and who knows how much time will be required to process the permit—longer range planning will be necessary. Reaction to an inspection calling for reconstruction will be delayed except in cases of a true emergency. It is recognized that most railroad bridge reconstruction is done with a certain amount of long range planning, but quite often this planning has been rather general and subject to last-minute adjustment of priorities based upon changing field conditions. Will this continue to be possible?

Of particular concern to our railroad, and I am certain to many of our counterparts, is the fact that when our roads were built, it was often the practice to build long timber trestles through river bottoms and other areas of low-lying ground, even though not required for drainage purposes, because trestle construction was less costly than building an embankment using mules and slip scrapers. This was particularly true where a source of fill was at some distance from the site. Over the last 30-year period we have had an ongoing effort to replace much trestle of this nature with fill as each trestle came up for renewal. This has been done both because fill would cost less than trestle construction, and to eliminate fire hazards and maintenance problems. Such fill has only been placed after a thorough drainage investigation was made and it was found that the old lengthy bridge was not required for waterway purposes. We made these thorough studies because we were no more interested in causing a flood or washing out our tracks than anyone else. However, on a non-critical branch line we may sometimes be willing to risk a slight wash-out at the bridge end during times of a 100-year flood to gain the lower cost benefit of the other 99 years of economical service. I do not consider this reckless management, but the question is now raised as to whether such self-determined options will continue to be available under the administration of flood-plain regulations. One would hope that they will, but we should be prepared to face the fact that they may not. Regardless of this feature, we probably will have to face the fact that it may take lengthy and time-consuming negotiation to arrive at permission to fill an unnecessary portion of an existing bridge.

The second involvement in this bridge replacement aspect can be in the type of structure to use. Except for main stream crossings, we have found the greatest economy in the use of trestle-type construction. Here I speak of treated timber trestles with 13-fc span lengths. We find these trestles to be satisfactory even though they do, from time to time during periods of high water, require the removal of quantities of drift accumulated on the upstream side. The closely spaced bents and the drift accumulation may cause a slight damming of stream which, while practically insignificant, may technically be an obstruction that will not be permitted. This brings out the economics of longer spans. On our railroad we replace from 10,000 to 15,000' lineal feet of timber trestle annually at a cost of approximately $300 per lineal foot. To replace this with steel or concrete trestle with span lengths in the 30-ft range would cost $600 per lineal foot. Longer girder spans in the 100-ft-length category, which could be required to pass moderately heavy drift, cost nearly $1,500 per foot. To go to truss spans of greater length raises the cost by two to four times this amount. What level of flood protection can we afford?

I am not bringing up the aforementioned examples as a scare tactic, nor as an attempt to talk against reasonable flood-plain management, but I am concerned about unreasonable or arbitrary administration of flood-plain regulations. In other aspects of my railroad duties I am involved in water pollution control. Here I have seen some very arbitrary and economically unjustified decisions by administrative bodies where they have forced us to toe the line to the letter of the law without regard for cost even though only a slight additional benefit would be gained. I would hope that this does not become the case in flood-plain management.

There are a number of problems that need to be considered by the railroads in connection with the management of flood plains. One is consistency in regulations. Our railroad, for example, operates in 13 states covering 283 counties and an uncounted number of townships. Theoretically, all of these units could have different flood-plain regulations. Hopefully this will not be true. We, in this far-flung industry, affected by geographically oriented differences, should work together for unification wherever possible.

In addition to working toward consistency of regulation, the transportation industry should strive, in every way that it can, to insure that permit applications are reviewed by competent personnel. This probably will be reasonably assured when dealing with the states and large metropolitan agencies. There is, however, a possibility that in the smaller units of government the review may be by non-professionals. Here, the problem exists of their not being aware of the consequences of arbitrary decisions. Nor may they have the background necessary for reasonable judgements. What, if any, the appeal process would be remains to be seen. But if an appeal is necessary, it will involve further project delay. This could be particularly significant in the field of industrial site location where the manufacturer to be served by the railroad must get his plant under construction on schedule if it is to be a profitable enterprise.

In summation, as for the impact of flood-plain regulation on the railroads, it becomes apparent that these regulations will require longer range planning in order to obtain the necessary permits for construction within a flood plain, and they may result in higher first costs. There will, of course, be compensating benefits; primarily the development of relatively flood-proof construction and the not insignificant benefit of management of the entire flood plain. This may preclude upstream construction by others of large building projects, parking lots, or similar features, which, in the past, have caused the railroad serious problems because of resulting increased rates of runoff.

I do not feel that the railroads need to be afraid of flood-plain regulation, as it has always been to our advantage to carefully design and construct our facilities in a manner that will minimize the risk of consequent flood damage. This has been done because the railroads have recognized that they are in business to stay and that they must live with whatever they build. Nevertheless, the probability remains that flood-plain regulation will increase the time required for the planning of a project and possibly will unnecessarily increase the cost of that project. This will be up to the judgement of the reviewing agency and hence not in our hands.

Restoration of Traffic Following Derailment and Fire on Truss Bridge

76–653–6

By N. E. EKREM
Director—Bridge Engineering
Burlington Northern, Inc.

The year 1974 was another memorable one for bridges on Burlington Northern. A year ago I spoke before this group about our prize-winning Latah Creek and Indian Canyon bridges in Spokane, Washington. They were very challenging projects. 1974 brought challenges of another kind. During the year we had at least ten major bridge disasters which kept us in a constant state of anxiety. Derailments, shifted loads, fire, high water and even impact by barges, all contributed to our troubles.

Today I will tell you about the one that started the year off with a bang and will show you a number of slides (not reproduced herein), better to illustrate some of the problems we faced.

The scene of my story is central Oregon, where there is a section of our line called the Oregon Trunk which goes from one of our main east-west lines on the north down through central Oregon and connects with lines extending into northern California. The Union Pacific has trackage rights over this line.

When our assistant vice president—engineering, Mr. Anderson, instructed me to go out to this derailment and give him a first-hand report on the extent of damage and what would be required to get the line back in service in the shortest possible time, he indicated that the bridge was not too accessible by highway. He was so right. There are no highways or public roads into the Deschutes River Canyon between Maupin, which is about 20 miles north, and South Junction which is about 10 miles south of the damaged bridge. The area to the west is the Warm Springs Indian Reservation. On the opposite side of the river from our tracks is a private jeep trail which was the only access into the area from the north, other than by rail. There are no roads in from the south.

During restoration we stayed in the town of Madras and drove about 25 miles to South Junction and took a motor car for about 10 miles to the bridge site. The remoteness of this location presented some real problems in getting men, equipment and material to the site expeditiously. My first trip in was by automobile over the jeep trail at a maximum speed of 10 mph.

On February 18, 1974, 19 cars had derailed and piled up on a 6-degree curve as the train was approaching the bridge from the north. The trailing or fourth unit of the locomotive derailed off the bridge. The third unit derailed and crashed into the end batter post of the bridge and the first two units were derailed entirely on the bridge.

After seeing a definite distortion or sag in the lower chord near mid-span, I wanted to get to the other end of the bridge for a closer look at the damaged span.

Looking down the left side, we saw that the deck was almost completely consumed by fire. It was no better down the right side, so we crawled through the locomotive units to get to the other end. What a sight. They were completely gutted by fire which had been fed by fuel from ruptured tanks and must have been intense.

Note: Discussion open until October 15, 1975.

I understand the train crew had attempted to fight the fire with extinguishers from the cab to no avail. They were just lucky the whole mess, including themselves, didn't end up in the river.

In the damaged truss, the steel in the two end panels wasn't too bad. The sag in the lower chord must have taken place when the fire was the hottest. In the upstream truss, the distortion in the top chord was gradual rather than abrupt. We noted some local buckling in various members but deemed them repairable.

It was decided that some members of the crippled truss would have to be replaced; other members would have to be straightened and/or repaired. Minor kinks or distortions could be corrected by merely applying heat.

Considering the extent of the damage we were of the opinion that we could save and repair the truss if (1) we could get the locomotives off without collapsing the whole thing and (2) if we could place false-work to support the span while crippled members were being changed out.

Removing the locomotives would not be an easy undertaking. Just what held the span up was a matter of some conjecture. It is my theory that the batter post was jammed against the locomotive which was cantilevered from the approach embankment. This condition provided some measure of end support. Then the fairly stiff upper laterals and sway bracing together with the stiffness of the floorbeams enabled the remaining load to be carried to the other three supports.

The locomotive was actually sitting right down on the floorbeams and crumpled rail. The obvious solution was to place falsework that would serve as a jacking platform for raising the units high enough to get ties and rails underneath and let the same falsework accommodate the truss repair operation. Driving falsework in that rocky turbulent river was out of the question. We had considered the alternative of collapsing the span and locomotives into the river, dragging them out and placing temporary fill or falsework to carry traffic while a new span could be procured but that was not in the least attractive. So we came up with the idea of filling a part of the channel and placing frame bents to serve as falsework.

Under normal circumstances it would take months to get such a scheme developed in sufficient detail to present for approval, additional time to get approval and still more time to obtain material and carry out the work.

We didn't have that much time.

To short-cut all this, Mr. Anderson joined us in Portland and we lined up a meeting with the contracting firm of Willamette Western to discuss steel repairs. After visiting the site with us, they considered our scheme feasible and gave us a proposal for furnishing the necessary fabricated steel, equipment and men for repairing the truss. Northwest Steel Fabricators of Portland were to prepare shop plans and fabricate the steel by the time we had the locomotives off the span. We furnished prints of original shop plans and our regional engineering people were active in providing liaison between Northwest Steel and my office in St. Paul to clear up design questions that arose. There were a number of questions since new members were weldments and in many instances required new splice connections to existing members.

Concurrently our B&B engineer and supervisors were lining up men, equipment and material for the falsework.

Obtaining fill material presented some interesting situations. A representative of Gibbons and Reed, an earthmoving contractor who was doing work for us elsewhere on the Portland Region, had visited the site on the day after the derailment and could move in men and equipment immediately to blast material from the high bluff overlooking the bridge. All we needed was approval from various state and local authorities and the adjacent landowners. Our regional officers made several contacts and applied for the necessary permits. We in the field understood approval would be forthcoming soon. Meanwhile the contractor was drilling for blasting.

Then the newspapers and politicians got hold of the story and the headlines were none too complimentary toward a large corporation that was planning to ruin the landscape.

Without further comment let me just say that our people finally got approval from the state authorities and were able to get quick approval from each of 16 Indians who jointly owned the land. Before anybody could change his mind we had enough material blasted loose and began moving it into the river (about 8000 cu yd).

(Mr. Ekrem then showed a series of slides to explain in detail how the bridge was restored).

Finally on March 10, just 20 days after the derailment occurred, traffic was restored over the bridge. Here I want to point out that we had faith in our work and didn't resort to putting a Union Pacific train across the bridge to try it out.

A few words about final cleanup and the effect of our work on the environment are proper as a conclusion to this story. I am going to take the liberty of quoting from a letter written by the president of the local chapter of the Isaak Walton League to the governor of the state of Oregon—and I quote:

"Dear Gov. McCall:

"The Deschutes Chapter has long been concerned with the Deschutes River, as you are aware. Potential and actual damage to the river and its environment is always possible, as with the Burlington Northern train wreck that occurred on February 18, 1974, at the bridge just north of Davidson Flat on the Deschutes River.

"I viewed the wreck two days after the occurrence and prior to any blasting. I then observed the work every day for the next week and reported to the Chapter on progress of construction. During this time there were many newspaper articles condemning Burlington Northern for blasting a unique cliff into the river and filling the river with rock to shore up the bridge. We decided at this time to keep our peace and to observe to the best of our abilities. Once the construction and clean-up were completed we would comment."

He goes on at length to describe the work which I won't repeat. Then continuing—

"On April 6, 1974 the Special Committee from the Chapter went to the site and examined the damage to and the resoration of the Deschutes River. Some steel and fuel barrels were present which have since been removed. The fill had been removed and all equipment was gone.

"The scar on the cliff is noticeable but appears to have enough dirt mixed in the rubble to start vegetation. The committee felt that within ten years the average person will not be able to tell there was ever any rock removed from the hillside.

"All excess fill from under the bridge was dumped along the existing railroad fill, graded and made an integral part of the fill.

"The river bank under the bridge looks substantially the same as prior to the wreck. Of course, what vegetation was there is gone, but will grow back.

"All in all, we feel what could have been a major disaster to this portion of the Deschutes has been averted by the expert handling of the situation by the Burlington Northern and the scenic waterway section of the highway department.

"We are always quick to criticize. Now we feel it is time to tell Burlington Northern, well done, and many thanks for protecting a beautiful canyon.

"We would also like to thank you, Gov. McCall, for your time and concern.

"On behalf of the Deschutes Chapter, Eric Ward, Chapter president."

And thank you, gentlemen, for your attention.

Railroad Scales—Past, Present and Future Applications

76–653–7

By J. L. FINNELL
General Scale Inspector
Louisville & Nashville Railroad

Along about the turn of the century the railroads were installing scales 40 ft in length, with a capacity of 66 tons. At that time the largest freight car was of 40-ton capacity, and those scales were adequate. I might add we still have scales of this vintage on our railroads today. In most cases they have been equipped with 100-ton weighbeams. The lever system is for the same 66 tons. The cost to install a scale of that vintage was from $1,500 to $2,000. This included the scale lever system, structural steel and scale pit.

Soon there was a demand for longer and heavier capacity scales. The freight car had increased to a capacity of 80 tons, and the railroads began to install scales 46 to 50 ft in length, with a capacity of 120 tons. About this time the railroads decided that they should be able to weigh cars in motion. The Streeter Amet Company had perfected a mechanical recorder that could be attached to the scale weighbeam for motion-weighing. This mechanical recorder consisted of a rod connected to the tip of the weighbeam that operated a rack and pinion attached to a wheel that had numbers on its outer edge. As the weighbeam moved in the upward direction when a load was applied to the scale, the rack and pinion turned the wheel until the weighbeam came to rest. There were treadles on the entrance and exit ends of the scale to count the car wheels onto the scale. When the car became scale-borne a 3-second mechanical timer assured the scale that the car was traveling at proper speed. If the wheel of a truck made the treadle on the exit end of the scale before the 3-second time period had elapsed, the print hammer would not be released to make a weight imprint on the paper tape. This worked fine for a time.

Then the freight cars began to get longer and heavier and the railroads began to install scales 50 to 60 ft in length, and of 150 tons capacity. About this time somebody said, "Look, we are having to weigh the bulk of our cars in two drafts on these short scales; why not install a 20-ft scale on a slight grade and weigh these cars in motion, in two drafts. The length of the car won't make any difference, and the gross weight of the car won't break the scale down, as we are weighing one-half car at a time." We still needed 3 seconds for each end of the car to be scale-borne and the weighmaster had to add the weights of each end of the car for a gross weight of the car.

About the middle 1940's, somebody said, "We want to put in classification yards, and we want a hump on a 0.75-percent grade, with a scale on the grade to weigh the cars as they drift over the hump into the yard." This required a scale to be at least 76 ft in length and at least 150 to 200 tons in capacity, with a mechanical recorder attachment; and we still had to have 3 seconds scale-borne time to allow the recorder type wheel to reach the weight and settle down for a good weight. This worked fine until somebody said we need to increase the length of our classification yard tracks, and we need to increase the number of tracks in our class yards. The

---

Note: Discussion open until October 15, 1975.

hump should be on a 3 percent grade, to get proper separation of the cars and to get the proper rollability of the cars, and the scale should be at least 92 ft in length. So in the early 1950's, we were installing scales 92 ft in length on a 3-percent grade, with a mechanical recorder. This recorder was mechanical with some electrical features added to it. The treadles on the rails had been replaced with an electrical switch, and the print hammer and timer were electrically operated; but we still needed 3 seconds for the type wheel to come to rest for good weights. A scale 92 ft in length, 200 tons per section, scale capacity 400 tons, on a 3 percent grade, cost 129,000 dollars; it had a scale pit 15 ft 6 inches in depth, 10 ft 6 inches in width, structural steel, upper bridge 30-inch-wide flange, 210-lb beams, lower bridge girder 36 inches, 280-lb wide flange girder.

In the year 1953, we thought this scale was the most: 92 ft in length and 200 ton per section capacity. This scale would never become obsolete, but it wasn't long until we noticed that every now and then we would miss a car weight. The freight car had grown in length again. About this time someone said, "Look, these classification yards work so good we ought to build another one, with more group tracks and longer tracks. We think the 3-percent grade is still good for car separation and rollability of the cars, but the scale should be not less than 105 ft in length." So here we are in the year 1958, with a 105-ft scale on a 3-percent grade.

Along about this period in time a scale manufacturer said, "Look we have something new on the market. We can eliminate the lever system and the weighbeam on these scales, and replace them with an electro-mechanical device, consisting of eight 100,000-lb-capacity load cells, a printer and console housing the electronic components." This sounded like the greatest thing that could ever happen to the scale business—no levers, no pivots and bearings, and no weighbeam. Could a gadget like this really work? Eight load cells took the place of the lever system. The load cell consisted of a column of steel machined to a specific length and diameter, with four SR-4 strain gauges cemented to the column to form an electrical Wheatstone bridge. This configuration measured the amount of strain, or deformation, of the steel column; as the column is deformed the strain gauges change in length and diameter and this changes the electrical resistance of the strain gauge. We excite these load cells with 10 volts input, and for every volt input we can get 2 millivolt output. At full capacity of the load cell we could get 200 millivolts output. This signal was received by the electronic console and amplified to a voltage to operate a servo mechanism. This system was really a null seeking device. When there was a null or no-voltage condition present, the system was at zero. When a load was applied to the scale platform the system became unbalanced. The signal from the load cells caused the servo mechanism to drive until the system became balanced again by the weight of the car. When the car moved off the scale the system became unbalanced again and drove back down scale until it reached a null or balanced condition. With this system we still needed 3 seconds scale-borne time to allow for the mechanism to drive to the weight of the car. We thought this was the answer to all of our weighing problems. I might add that this scale's complete cost was 125,000 dollars. Between 1958 and 1963 we installed two more of this type system on our railroad.

About this time the scale manufacturer said we have a new type system you can replace that old servo mechanism with, and you can weigh a car in 1 second instead of 3 seconds. We had been hearing about solid-state this and transistorized that. In 1965 we installed our first solid-state electronic track scale. It was 20 ft in length for uncoupled-in-motion two-draft weighing. This scale weighs a truck of the car and holds it in memory or storage, and weighs the second half of the car and prints out a gross weight. In 1967 we installed another one of these scales, with the readout located better than one mile away in the main yard office. We thought this was the ultimate in the weighing business, but it wasn't long until we begin to hear rumors of coupled-in-motion weighing on scales of various lengths from 3 ft to 5 ft 3 inches in length, weighing freight car axles, coupled in-motion, and giving out a gross weight for each car; and scales of 12 ft 6 inches to 15 ft weighing cars in two drafts coupled-in-motion. Our Committee 14—Yards and Terminals Scale Subcommittee was running all over the country gathering data on this mode of weighing.

In 1971 the L&N management decided we ought to have two of these scales somewhere in our main lines in the coal fields, and by the end of 1971 we had a 12-ft 6-inch coupled-in-motion two-draft scale installed in our main line on two divisions in the coal fields. One is located 7 miles out of Corbin, Ky. and one 8 miles out of Ravenna, Ky. These scales are completely automated, and they are unattended. When a train comes into the track circuit the scanner is turned on. (I failed to tell you these scales are equipped with a scanner to take the car numbers off the car.) The scanner is turned on and tells the scale there is a train coming in the proper direction to be weighed. At that same instant a header that consists of a message number, date, time and location of generated message is recorded on a teletype located in a yard office 8 miles away, and at the same instant is given to the master computer located some 800 miles away.

When the engine of the train is 500 ft from the scale, it comes to two sensors located 30 inches apart on the rail. When the first sensor detects the presence of the first wheel of the engine, the scale will turn on and give a system reset and interrogate itself for zero. If the scale is working properly the computer and teletype will receive the number 50000, telling them that scale is in proper working order. If the scale is not in proper working order the number 90000 will be sent to the teletype and computer. The computer is programmed not to accept any weights if it receives a bad turn-on from the scale. If the scale gives an indication of good turn-on (50000), and the second sensor detects the first wheel of the engine, the speed indication light comes on along the right-of-way throughout the entire length of the train. At this time the two sensors will take over the job of indicating to the engineer that his train is moving at proper weighing speed by the time it reaches the scale. The speed indication consists of a lunar white light. When the train is at proper speed the engineer will observe a steady light; when the train is nearing overspeed the light will flash at a rate of 60 times per minute; when the train exceeds 5 mph the light will flash 120 times per minute, telling the engineer that his train is in overspeed. The weights of any cars passing over the scale at this time will be inhibited and the number 90000 will print out for weight of the car.

There are three more sensors located on the rail just before the train reaches the scale. These sensors tell the scale, this is a 4-axle engine, inhibit the weight; or this is a 6-axle engine, inhibit the weight; or this is a 4-axle car, weigh it. Located on the scale are three more sensors. The first sensor on the scale has several jobs to do; it counts the wheels and tells the scale this is the first half of a car, store this weight. During this time the scanner has looked for a car label and printed out a car number, and by this time the second half of the car has been counted onto the scale; and the scale says to the scanner, are you ready for the gross weight of this car to add to your car number? The scanner says yes, and takes the weight and passes this information on to the teletype and computer. This goes on until the entire train is weighed. As the computer receives the car number and weight information it reaches into a bank of stored tare weights and matches a tare weight to the car number, and makes the necessary subtraction for a net weight on each car, then sends the entire message generated out on 1050 machines to locations for car billing.

Now let's go back to the first car coming onto the scale. I told you that the first sensor on the scale had several jobs to do. It counts the wheels for weight storage, giving the computer the gross weights. At this time the sensors located 500 ft away that have been controlling the speed indication are now inhibited and the first sensor on the scale and the sensor at the exit end of scale take over the speed indication. The truck must be on the scale 0.50 of a second for a good weight. If the exit sensor detects the presence of a wheel before the 0.50 of a second, the weight will be inhibited and a fast condition will be indicated to the engineer on the speed light along the right-of-way, and a 90000 will be generated for the weight of the car. Now let's see what the middle sensor does located 6 inches center to center from the first sensor on the scale. This middle sensor has one job to do and that is to detect a reversal of the train, should the train have to be reversed due to missing weights, due to overspeed, or a sensor failing to detect a wheel count, causing the scale to get out of cycle and into a resync condition, which would inhibit the weights. The train is reversed and the middle sensor detects the wheel before the first sensor does. The scale knows that the train has been reversed and all programming will be inhibited, except that the axles are being counted and stored, up to 256 axle counts or 64 cars. Now the train starts forward and the scale starts counting down and when the axle that started the reversal reaches the scale, all programming will start again and weighing will continue where it was inhibited on that particular axle.

Now let's look inside the scale house and see what makes all this happen. The cabinet contains eight amplifiers, one for each sensor on the rails. These amplifiers generate a relay closier telling the scale how to program for 4-axle engines or 6-axle engines or a 4-axle car to be weighed. This cabinet contains the real brains of the system. If you look at the front panel, you will see a number of control buttons and lights. Reading from left to right at the top there are three speed indication lights—green for normal or good weighing speed, yellow for caution or near overspeed, and red for overspeed. To the right of these lights are two buttons for weigh and standby. In the second row to the far left is the gate lamp. This lamp indicates when gate opens and allows the counter to look at the weight for a 0.50 of a second, then the gate closes and scale gives the weight to the scanner. To the far right there are two more lamps, the cycle and count indication. When a vehicle is entering the scale the count light will come on and stay on until all the axles have been counted for that particular vehicle, then the count light will extinguish and the cycle light and gate will come on telling the scale to read a weight. On the bottom row to the left is a button for automatic or manual scale operation. To the right there are four lamp indications—engine detection, out of cycle or resync detection, and a reversal indication. To the far left are indications as to the number of axles the vehicle passing over the scale has.

Now let's look inside and see all the "goodies" that cause all this to happen. On the right side of the cabinet, there are two power supplies for the load cells. We excite these load cells with 20 volts dc and the output of the load cell is 2 millivolts per volt input. At full capacity of the 200,000-lb cell we could get 40 millivolts output. Just above the load cell power supply you will see a master junction board, and an integrated controlled oscillator or I.C.O. The master board collects all the millivolt outputs from the load cells and passes them on to the I.C.O. The I.C.O. changes these millivolts to a frequency and passes the frequencies on to a frequency counter. The frequency counter takes the signal and processes it through a number of decimal counting unit boards, or D.C.U. boards, from 10 to 1 power to 10 to the 5th power, and the information coming out of the counter to the scanner will be in binary coded decimal units or B.C.D. or numbers. This next drawer or rack of boards does all the programming and tells the counter the exact millisecond to pass its information to the scanner for weight of the car passing over the scale.

With this system, should we have a failure in transmission to the computer located in Jacksonville, Fla., we can store the car numbers and weights of 700 cars at the scale, and when transmission is resumed the computer will pole this station for messages as stored. At the same time the weights and car numbers are being stored, the clerk in the yard office 8 miles away can switch to a weights-only teletype and capture the weghts only, no car numbers, for train being weighed.

We think these scale systems are the past, present and future: but we are reminded that we have only scratched the surface in the electronic field.

Now let's look at another type of weighing that has helped the railroads in car utilization, and helped the coal industry in production of coal. In our western Kentucky coal fields we handle 700 car loads of coal per day and 66 percent of this coal is handled in unit train, flood loading on loop track operations. The train comes into the loop track and when it reaches the loading facility, slows down to a very slow speed and the flood-loading begins. At most of these facilities a 100-ton car can be loaded per minute. The coal is flooded onto a conveyor belt that passes over a belt conveyor scale and into a surge hopper or bin. This bin has gates that the loading operator can control to prevent spillage of coal between car loadings as the train moves slowly around the loop and towards destination. A 100-car train can be weighed and loaded and on its way to destination in about one hour and forty minutes. To obtain good weights on a belt conveyor scale, it must meet all the requirements set forth by the weighing bureau, such as incline of the belt, impact rollers where the coal is flood-loaded onto belt, and proper counterbalance weight to prevent belt from slipping on the belt drive. Belt feeders must be controlled to keep the belt burden not less than 0.50 and not more than 0.85 percent of belt capacity. The scale must be protected from wind and weather, must have an alarm system to alert the operator as to belt burden, and a strip recorder chart that can be filed away for policing the weights derived from the scale. The scale must also be equipped with a printer for billing of unit coal and individual cars, whichever may be the case. These scales must meet a tolerance of 0.25 of 1 percent when being material tested, and the belt scale must be chain tested each week with a chain calibrated to a specific weight to simulate normal operating conditions. A copy of the chain test must be mailed to the railroad scale department and the Southern Weighing and Inspection Bureau, which has jurisdiction over western Kentucky. This mode of weighing and the handling of unit trains has certainly enhanced the coal industry and the railroad's operations.

ACI/CW1M *Sample Printout From Computer:*

```
     (1)       (2)        (3)        (4)                    (5)
    -ACI-  /AD064ZZZ946C0RDECLNSZZZ                        GRY910
    002 0461554NGR1.
(6) 50000
    9LOCO      1331
    LN        22613       2190       1750       1440
    ATSF      47335       0639
    LN        22615       0730       0740       0000
    LN        30630       1649       0591       1058
    LN        22935       2240       0750       1490
    LN         8203       1290       0484       0806
    LN       184011       1946       0515       1431
    RI        12458       0568
    LN       181051       2053       0527       1526
    LN       183620       1993       0517       1476
    LN       154737       1974       0522       1452
    LN       132433       1554       0402       1152
    LN        84718       1578       0415       1163
    LN       135754       1620       0405       1215
    LN       180649       2137       0531       1606
    LN       151286       2035       0515       1520
    LN       188877       2174       0434       1640
    0000000000            1988
   8LN         1178       0480       0480       0000
    TRAIN TOTAL         030838     008678     018975
    -EOT-
    72046           1651     CT  025
```

(1) Type Of Message.

(2) Processing Program and Sequence.

(3) Terminal and Sequence of Message Received.

(4) Terminals Message is Addressed to.

(5) Identifies Message Origination.

(6) Good Scale Turn On.

Teletype Output

Sample Printout

```
(1)  (2) (3) (4) (5)
004  0481055NGRI
 50000
9444001333–2 90000  (6) (7) (8) (9) (10) (11)
9444001334–1 90000  (9444001334–1 90000)
0444150479–5 51942  (0444150479–5 51942)
0444139386–0 51597
0444082399–3 51522
000000000000 51528
0444185674–9 51970
000000000000 51566
000000000000 51479
0444185783–2 51976
0444150802–3 51933
0444151568–1 51937
0444150657–1 51977
0444131161— 51555
0444115368–5 51455
000000000000 51912
0444151421–6 51927
0444117619–2 51470
000000000000 51595
0444152136–5 51931
0444155131–2 51934
8444001097— 50488
–ECT–
```

(1) Sequence Number.
(2) Julian Date.
(3) Time.
(4) Train Direction.
(5) Identifier Scanner Station.
(6) Equipment Type.
(7) Owner Code.
(8) Vehicle Number.
(9) Parity Check Digit.
(10) Weight Condition.
(11) Gross Weight.

Weight Only Mode Teletype

Sample Printout

```
                        Digits For Trouble Shooting
000000 1 or 2 (1) Good Turn on Calibration.
000000 36     (2) Bad Turn On Calibration.
000000 36     (3) Engine.
190400        (4) Out of Cycle Or Resynchronization.
157000        (5) Overspeed.
230000        (6) Six Axle Car
147500        (7) First Weight After Reversal.
182700        (8) Eight Axle Car.
156500        (9) Power Failure.
151200
158100
151700
190500
 80400
 95300
165400 4
000000 5
000000 6
000000 8
000000 9
```

The Reading Company's Foreman's Training Course

76–653–8

By E. C. LAWSON
Chief Engineer, Reading Company

Before presentation of the subject at hand, I wish to extend my appreciation to "Herb" Archdeacon, engineer of track of the Reading Company. Without his personal effort and diligence in following through, our program would have had no success whatever.

Historically, training of foremen in the track department, at least on the Reading, has been through the route of "Monkey See—Monkey Do." The track supervisor or foreman spotted a man who they thought had some potential and started to show him how they did things. Usually, one of two things happened. The man learned enough so that when his boss, the section foreman, retired, he was the obvious man to take over. Before mechanization, this was a fairly satisfactory arrangement. Or maybe an opening for a sub-foreman's job came up and he had enough seniority as a laborer to be the successful bidder. If his performance was satisfactory, he continued as a sub-foreman until he learned enough to advance to foreman. In most cases, this process took many years and again yielded satisfactory results, particularly when forces were fairly stable and most work was performed by hand.

We can no longer afford the luxury of this type of training, nor the type of organization which permitted this.

With the sophistication of mechanized operations and reduction, if not elimination, of section gangs, the old training grounds were disappearing and, along with this, our good, well trained foremen were retiring.

A couple of years ago, we realized that something had to be done to provide ourselves with foremen who were capable of handling inspection and repair of tracks and operation of tie, surfacing, and rail laying gangs, to mention only some of the areas of concern. And how could any of us forget the institution of the FRA Track Safety Standards in 1972.

No longer were there section foremen who were responsible for a small portion of the railroad, but rather a reorganization which consisted of district gangs and mechanized tie, surfacing, and rail laying operations. At this time, section foremen were gradually retiring and we realized a couple of years ago that something had to be done to train foremen in the proper method of track maintenance, inspection and construction.

The question was raised how to go about getting these men from the ranks, training them, and having them do the job that was necessary. We decided we must investigate other means of training. We inquired of several railroads throughout the country as to their procedures and methods of getting properly qualified track foremen. While a few railroads did have some training programs, we did not feel that any of these approaches were suitable insofar as the Reading was concerned and decided that we would attempt to set up a formal training program.

In addition to the necessity of training foremen to replace those leaving the service, we were aware that we had foremen, or I should say men filling foremen's

---

Note: Discussion open until October 15, 1975.

positions, who were not adequately trained to handle the responsibilities of those positions and felt that upgrading of these men was also necessary. However, if these men were to be retrained, we would have to train new men to adequately cover these positions while they were in training. It was, therefore, necessary to initially train men who did not have any rights as foremen, but who had the potential of assuming these responsibilities.

As a result, we decided our program should be broken into two segments, the first being to train new men, not only to fill the positions of the men whom we intended to retrain in the future, but to take up the slack which we judged would be necessary due to future retirements, etc. The first concern, then, of course, was the development of a program for training of personnel who had never held a foreman's position.

What are the major considerations in setting up such a program? Some of those which we considered were:

1. How many men needed training?
2. How would these men be selected?
3. What kind of an agreement would be necessary with the organization?
4. What areas and subjects are to be covered?
5. What do we need in the way of a faculty?
6. What do we need in the way of facilities?
7. How much would it cost?
8. Must we secure authority from management?
9. What other areas might we want to consider in the future?

Let us take these, one at a time, and see briefly how these questions were answered on the Reading.

First: An analysis of our situation in the early part of 1973 indicated we should immediately train at least 30 men.

Second: We felt that each person had to have certain qualities, namely:

1. Some leadership potential.
2. A desire for advancement.
3. A reasonable command of the English language.
4. A reasonable degree of confidence in mathematics.

Third: We arrived at an agreement with the Brotherhood of Maintenance of Way Employees which covered the following essential points:

1. The number of "foreman trainees" to be included.
2. Method of selection.
3. Supervision of program.
4. Length of program.
5. Hours per day.
6. Testing and evaluation.
7. Compensation while at school.
8. Establishment of foreman apprentice roster with rates of pay.
9. Requirement of foreman apprentices to accept positions.

Referring to Items 1 and 2—Agreement provided for 16 foreman-trainees to be selected jointly by the engineer of track and the assistant general chairman of The Brotherhood of Maintenance of Way Employees after applications had been received. Any insurmountable disagreement was to be referred to the labor relations department.

The carrier was to designate an officer to supervise the program, which would consist of approximately 75 days of training. While the trainees were to put in 40 hours per week, flexibility was permitted so that, if for some reason, such as a field trip, more than 8 hours in one day were consumed, another day could be shortened. No penalty time was paid. The agreement provided for testing and evaluation by the carrier, with the absolute right vested in the carrier to determine the suitability of a trainee. The trainees were compensated at the rate of the position held immediately prior to selection to the school and an expense allowance of $10 per day. Upon successful completion of the course, a roster of foremen apprentices was established with a set pay scale. They were *required* to accept assignment to temporary and regular positions as foremen on their seniority districts. When filling temporary vacancies, they were to be paid a travel allowance which varied with the distance from their home headquarters.

Fourth: In addition to the obvious areas of track maintenance and inspection, the following were to be covered:

1. Company policy as it affects the foremen.
2. Records and reports.
3. Rules of the operating department.
4. Personnel policy.
5. Mechanized operations.

Fifth: A full-time director was deemed essential whose duties would include:

1. Development of lesson plans from an outline which had been prepared by the engineer of track.
2. Instruction of major portion of the course.
3. Conducting quizzes and maintaining record of trainees' progress.
4. Arrange for supplemental instruction both within Reading Company and from outside sources where necessary.
5. Arrange for and developing teaching aids, such as movies, slides, brochures and demonstration material.
6. Administration of budget established for the course.
7. Arrange for housing, transportation, etc.
8. Provide trainees with all necessary publications, tools, safety equipment, etc.

Sixth: A classroom site was selected at a central location on the System at Reading, Pa., immediately adjacent to the maintenance of way equipment shop. At this point, most equipment would be available for demonstration purposes and field trips could be made for demonstrations, as well as practical application of the classroom work.

Seventh: On the basis of the foregoing, a budget was established which indicated a cost of approximately $3,800 per man, including wages; however, in most cases the man's present position was blanked and the resultant cost was approximately $1,000 per man.

Eighth: In the middle of August 1973, authority was secured from Reading Company's management to proceed.

Ninth: It is our intention to set up a program for machine operators as soon as our re-training classes are over and subsequently a refresher course for track supervisors and assistants.

After hiring a director in October of 1973, work was begun in earnest to develop a detailed program from the preliminary outline previously prepared. As fully developed, the course outline lists the subject to be covered, the estimated time, the instructor, whether it is in the classroom or in the field, topics to be covered and visual aids to be used. Our first class lasted 14 weeks. In addition to the outline, a lesson plan was prepared, detailed notes were distributed, and a test conducted.

In the meantime, an agreement was signed between the Company and the Brotherhood of Maintenance of Way Employees. Incidentally, we had excellent cooperation from our general chairman, Sal Freccia.

By January of 1974, approximately 25% of the course details had been developed and it was time to set up our classes. We felt that a class of 30 would be too unwieldy and decided to operate at least two classes.

Notices were posted on all bulletin boards throughout the System and, after applications were received, meetings were held with the applicants, at which time the purpose of the school was more fully explained, as well as the compensation arrangements. A time was allowed for questions. A representative of the organization, as well as our own track people, participated.

Before the meeting concluded, aptitude tests were administered by our personnel department. On the basis of these tests, 19 students were selected for the first class and we were off and running.

Our complete manual for the entire course makes quite a volume.

It might be well to mention here that field trips were scheduled to our tie treating plant and to all the different mechanized operations. The class also visited Bethlehem Steel Corporation's rail mill at Steelton, Pa.

Also, while a number of our visual aids were prepared in-house, we were able to secure a good number of films from various suppliers, some of whom incidentally also provided instructors. We even had a representative from the FRA speak to the class about the Track Safety Standards.

From within the Company, we drew instructors from the following departments:

1. Safety
2. Operating Rules
3. Accounting
4. Police
5. Signal
6. Communications
7. Stores

Two of the original 19 were washed out for various reasons, but on May 14, 1974, 17 men were graduated from the school with the title of apprentice foreman.

Due to our experience with the first class, some adjustments were made in various subjects and the total time reduced to 12 weeks. On August 28, 1974, we graduated our second class of 13 men.

Incidentally, we held a luncheon for each of the classes and presented them with diplomas indicating their successful completion of the course.

We are now conducting classes to upgrade the skills of our existing foremen.

How successful have we been? It is not easy to evaluate in such a short period of time. We do know that every apprentice foreman either is now, or has been, working a foreman's job—some on a permanent basis because of the reality of the predicted vacancies and some temporary while the regular foreman is at school.

There is a definite feeling among our supervision that at least we have men out on the ground who are better prepared to assume the responsibilities of a track foreman than we have had for many years.

An Outline of the Past, Present, and Future of Engineering Training on Canadian National Railways with Emphasis on Roadmaster Training

76–653–9

By J. S. BUSBY
Assistant Chief Engineer Administration
Canadian National Railways

PREFACE

There appear to be only three or four North American railroads which have any major training going on at this time, and of these none has reached our point of sophistication. Work is underway to develop costing of the training materials used in C.N. Engineering programs, and copyright arrangements are under active investigation to protect against misuse of the materials, quotes out of *context,* etc.

Canadian National Railways is a government corporation, operating in all 10 Canadian Provinces, the Northwest Territories, and in 11 States. Canada is an officially bilingual country with French and English predominating and several other languages, notably Italian, Portuguese, Ukranian, etc., appearing at various locations across the country.

The C.N. system is divided into 5 geographical regions along with our associate, the Grand Trunk Western Railroad, each with its own vice president, chief or regional chief engineer and other functional staff. System headquarters is at Montreal, where the chief engineer and his staff reports through a vice president of operations and maintenance to the president.

We are monitored by a Federal group, known as the R.T.C.—The Railway Transport Committee, who sit at Ottawa. This group roughly equates to your ICC. C.N. operates over approximately 25,000 miles of main track, of which about 1,700 miles are in the U.S.A. The engineering staff consists of about 13,000 people, all told, of which about 2,000 are management and support staff and within this group there are about 60 track supervisors and 255 roadmasters.

My purpose in being here today is to present some of the history of Engineering Training in C.N., what is presently available to our people, with emphasis being placed on roadmasters, and what we see in the future.

Thirty to 40 years ago, *non-professional* promotion in engineering frequently fell to the man who had the biggest shoulders or the loudest voice. Also, not too long ago, it was the custom in Newfoundland that the father taught the son the intricacies of section maintenance or hoist operation and when the father retired the son got the job and that was that. Simple-effective-uncomplicated. In the Province of Quebec the man who was unilingual French speaking needed at least to be able to count, swear and read a line-up in English, before he could hope for promotion. Fortunately, these archaic practices have disappeared.

Note: Discussion open until October 15, 1975.

Most Engineering Training that existed took the form of an apprenticeship activity—which includes in it standard methods of procedure, along with the perpetuation of errors.

In 1955, our signal department organized a signal training program which is now recognized as being one of the most sophisticated on the continent. It presently includes electronics, is mandatory for all scheduled ranks and forms a part of the agreement between the Railway and the Brotherhood of Railroad Signalmen (B.R.S.).

In the late 50's, our work equipment department, that is, the group which operates and maintains the track maintenance machinery, started some regional training courses, primarily to teach their men to operate maintenance machines. This kind of training has continued and in 1970, following the lead of the Atlantic Region, a four-year mechanic training program in heavy equipment repair was commenced on all regions. To date, about 11 graduates have successfully completed that course which, in some Provinces, is operated as a joint venture between C.N. and the Provincial Institutes of Technology or similar schools.

Again in the late 50's, our bridge and building department, recently re-named to bridges and structures, created a one-shot B. & B. foremen's training course in Winnipeg, Manitoba. Although this course was extremely well given, thorough, and achieved its purpose, it gradually fell into disuse. There was a limitation as well in that the course was available in English only, which restricted participation by certain foremen who were unilingual French-speaking.

In the early 1960's, some regional track training courses took place, aimed primarily at roadmasters and assistant roadmasters. These were designed to both upgrade the marginal performers and ensured that the men knew the jobs they were being paid to do. That training was handled locally, by the most knowledgeable track people and, again, served its purpose well at the time; but there was no interregional communication, standardization of methods or overall co-ordination of these sporadic efforts.

As the 60's progressed, a series of pressures began to build within the C.N.R., which gradually turned our attention toward ourselves with ever-increasing thoughtfulness. Due to budgetary constraints, increased mechanization, re-organizations and attrition, our track maintenance and bridge and building forces were substantially reduced in the 1959–1969 period—leaving, at that time, a total track and B. & B. force of about 8,700 men. It was also predicted that 30% to 40% of this manpower was subject to turnover within the next 8 years.

The older men had left—leaving a gap of knowledge and skills; the younger men, many of them promotable, couldn't hold jobs due to seniority, and we were left with a core of personnel who were feeling insecure about their future. Some men with as little as 6 months of service found themselves as foremen on a branch line with a few either green or fearful sectionmen to back them up. The average age of section forces on one of our regions as recently as four years ago was 55 years.

As the concentration by management on planning, programming and production increased, and as the complexity of mechanized maintenance intensified, there were many track officers—roadmasters, and assistants particularly—who found it just too difficult to compete in a rapidly-changing, technologically-oriented Railway. These people gradually withdrew, again leaving a void of knowledge and skills *which were still needed,* no matter how technical or mechanical we became. Superimposed on this situation was a gradual traffic increase, heavier axle loadings, speed increases either installed or requested, less track-time available to perform maintenance—with the resultant gradual plant deterioration and a gradual increase of track-related accidents.

The installation of the Canada Labour Code limited the hours that we could ask a man to work, both regular and overtime. The Brotherhoods were reacting to a gradually deteriorating situation in trying to protect such men as they had left and forecasting a distressing future. The severity of the situation was underscored by the Railway Transport Committee's top-level hearing with Canadian railways about 5 years ago.

How, then, did engineering management react to this situation?—with an increase of mechanization on the sections, improving housing conditions, locating many section headquarters to within reasonable reach of some social amenities. Radio communication was, and is continuing to be, improved. Some salary increases were granted and "designated allowances" were made in view of particularly difficult territories. Overtime was starting to be paid to supervisors and officers. In one extreme case, we ferried men from their headquarters to and from work by helicopter. This activity has now ceased.

We stepped up the issuance of our Standard Practice Circulars (the "WHAT" of maintenance), and Technical Information Bulletins (the "HOW" of maintenance). A revised set of Maintenance-of-Way Rules was written and we are still struggling to produce a more workable set of Track Motor Car Operating Rules. Continuous welded rail is being laid over ever-increasing mileages and concrete ties are in their infancy. Speeds of some of our larger locomotives have been reduced on curves with a dramatic reduction in track-related derailments.

Notwithstanding all these activities designed to improve working conditions and methods, there remained the need for training our forces *JUST TO DO THEIR JOBS*. This gave rise, on 1 January, 1970, to the policy that system engineering would co-ordinate the training of all ranks of employees, within this department. This evolved within an existing System Management Policy (1963) which reads, in part, as follows: "All vice presidents, department heads, and other officers delegated by them, have authority to initiate and organize training activities for employees under their jurisdiction, and to call for assistance from training and other specialist groups at system and regional levels."

How then was the Policy to be implemented? An organization was created within the chief engineer's office, under the responsibility of the assistant chief engineer—administration. A project development officer, a project co-ordinator, and a training development officer were assigned specifically to develop a training program. We went searching for, and found, a man with a "heavy" track background, as well as having some "people" and "communication" skills. The terms of reference given him were, "Gather and organize any and all material, within and outside of the Railway, which would in any way, contribute to track training and participate in the development of a suitable training program for track personnel, up to and including roadmasters."

Sixteen months and three thick volumes of information later, the study was completed, reviewed and refined to the point where we were able to clearly identify, among several other related items, what subjects needed to be taught and who needed them. In the process of refining, a one-week seminar was held in Montreal in which 16 of our most knowledgeable roadmasters and track supervisors took part. It should be noted here, that only one engineer and one technologist participated.

From this seminar flowed several recommendations, many of which were quickly or eventually implemented:

(a) Don't forget subjects which may be unique to a region.

(b) Regions to estimate the numbers and kinds of personnel they had who needed training and how many could be spared at a time.

(c) Appoint regional training supervisors to co-ordinate the system-region approach to training and participate in training to the extent their backgrounds allow.

(d) Training facilities be supplied by the regions.

(e) Training must consist of both the field and classroom type of instruction.

Regional training supervisors were then appointed, and soon became actively engaged in preparing lessons, which would lead to regional training.

This, then, was the situation toward the end of 1971.

In taking our first few faltering steps toward formalized track training, it was considered that to get the most information to the most people as quickly as possible was of prime importance, and all training would be done "in the field" by roadmasters to foreman and men. This required that the roadmaster train his men in one course at a time, in subjects where there was an apparent lack. Thus the roadmaster became the trainer.

There were some advantages to going this route:

(a) A large volume of track personnel was trained *in a few subjects;*

(b) Training was done relative to the needs of the territory;

(c) Productive work was performed in learning *some* of the subjects.

(d) It involved the roadmaster in training his men (which after all, is part of his job) and the roadmaster, in theory anyway, would upgrade his own skill.

(e) There was an obvious economic advantage in that there were no classrooms needed; travelling involved only one man and the trainees were comfortable in the "field" environment.

It began to become apparent, however, that the "field-only" method of proceeding was not sufficient to achieve total training as we had envisioned, even though the field training had (and still has) merit for specific items and people. Excessive time was needed by the roadmaster which was detrimental to his other duties, and there were varying degrees of abilities and commitment evident among this group. The method needed continuous monitoring and impetus to ensure its perpetuation. It also became apparent that something had to be done to prepare the roadmaster *BEFORE* he could be comfortable as a teacher.

The "classroom-field" method was what was needed to enable us to embrace the total training responsibility.

There was available in other departments of C.N. at that time a course known as the "S.I.T." course—"School of Instructional Techniques." This was quickly condensed into a three-day "Effective Communication" course to which nearly all of our 255 roadmasters have now been exposed, along with several other engineering officers.

The instructional material with which roadmasters had been furnished at that time (1972–73) reflected the haste with which it was prepared, and pointed up the necessity of spending the time in proper preparation.

Emphasis was then beginning to swing toward the "course" as opposed to the "lesson."

At this time, another situation was shaping up in that not only were we being hard-pressed to provide roadmasters to conform to our own specifications for track inspection and maintenance, but there were indications, again, that our R.T.C. would impose even heavier responsibilities on track inspection activities which, in turn, would create the need for more roadmasters, assistant roadmasters, foremen, etc., and *we didn't have the men properly trained to do the job.* Consequently, in early 1974, two system-administered schools were created in haste at Belleville, Ontario, and Levis, Quebec, the purpose of which, at that time, was to instruct as many roadmasters and foremen, as quickly as possible, HOW TO DO THEIR JOBS. Trainees also included the newly-appointed, the about-to-be appointed and the under-achiever.

School locations (Fig. 1) were chosen with consideration given to population concentration, language differentials, social and recreational facilities, ease of access, and the availability of satisfactory trackage and track conditions where the theory learned in the classroom could be practiced on the track. The facilities at these two locations are still in use and are portable, in that they are located in rented facilities. (Our experience with a mobile, on-track instruction car a few years ago was not encouraging.) Smaller C.N. training schools have been created at some regional headquarters—notably, Moncton, New Brunswick and Winnipeg, Manitoba, where regional training is carried out from time-to-time and again refers to special needs of the time and/or location.

All those who operate the two schools (Fig. 2), from the senior instructor on down, must be seen as "comers" who primarily are able to do the job and who also will benefit from the two to three years of experience in that kind of work. We see that exposure as being every bit as important to a man's development as, say, operating a rail or tie gang or being sent on other purely track-related special projects.

Let me say this to those of you who may be contemplating or in the process of setting up training personnel—make it known that these are NOT "retirement" jobs, or a nice comfortable place to vegetate. There is no place for nepotism, since there is too much at stake to accept under-achievers into training administration.

We have a series of persons as a "back-up" or "resource" group, none of whom is on our staff, but are lent to us from various regional and system sources. One very important person is our translator, a one-time roadmaster, who is full-time engaged in translating lesson material and technical papers from English to French. (French speaking trainees represent about 20% of our forces). Another is our system supervisor, track maintenance, who has been seconded to us by the maintenance group for two years now. Without this most essential input to the program, we could be much further behind in our capabilities than we presently are.

(Text continued on page 546)

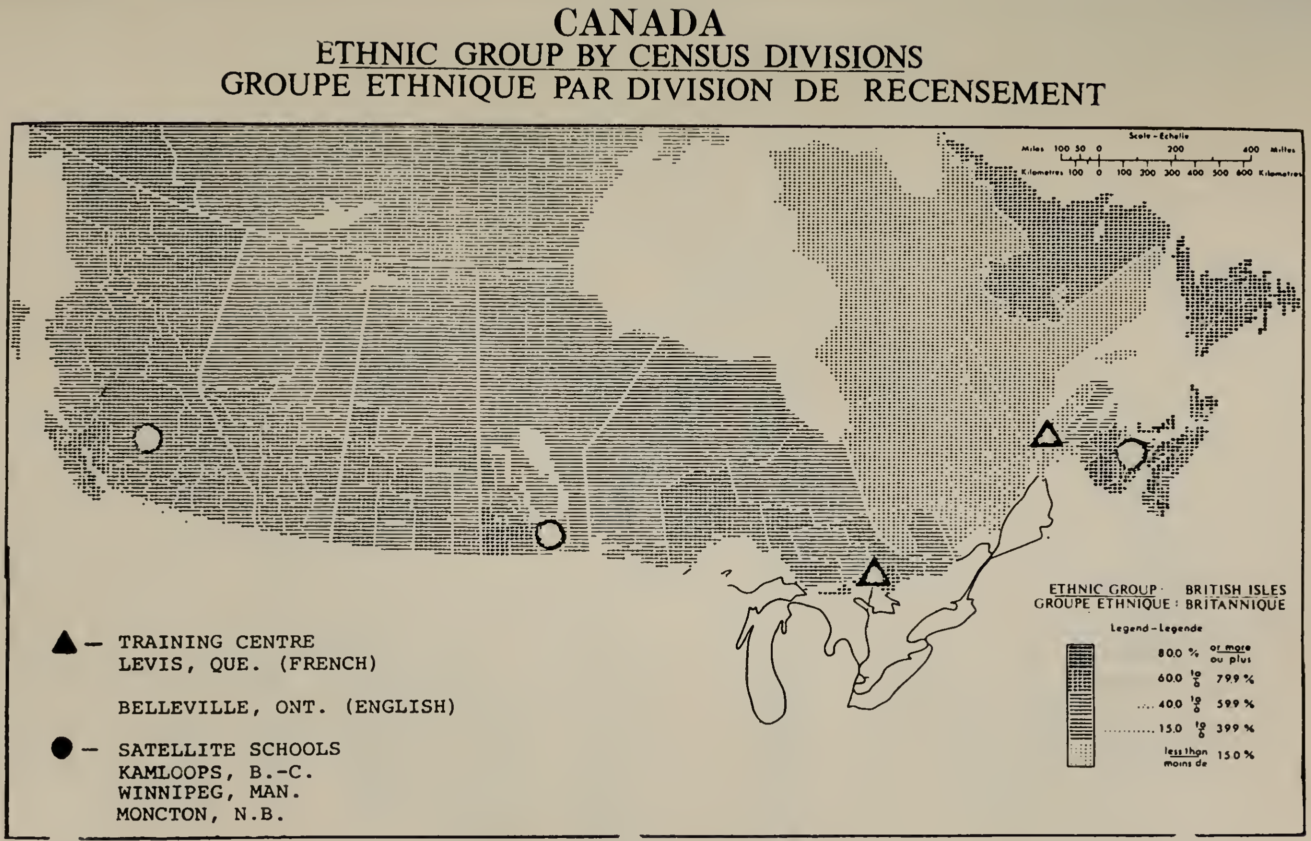

CANADA
ETHNIC GROUP BY CENSUS DIVISIONS
GROUPE ETHNIQUE PAR DIVISION DE RECENSEMENT
Scale - Echelle
Miles 100 50 0 200 400 Miles
Kilometres 100 0 100 200 300 400 500 600 Kilometres
ETHNIC GROUP · BRITISH ISLES
GROUPE ETHNIQUE : BRITANNIQUE
Legend - Legende
80.0 % or more ou plus
60.0 to à 79.9 %
40.0 to à 59.9 %
15.0 to à 39.9 %
less than moins de 15.0 %
▲ — TRAINING CENTRE
LEVIS, QUE. (FRENCH)
BELLEVILLE, ONT. (ENGLISH)
● — SATELLITE SCHOOLS
KAMLOOPS, B.-C.
WINNIPEG, MAN.
MONCTON, N.B.

Fig. 1

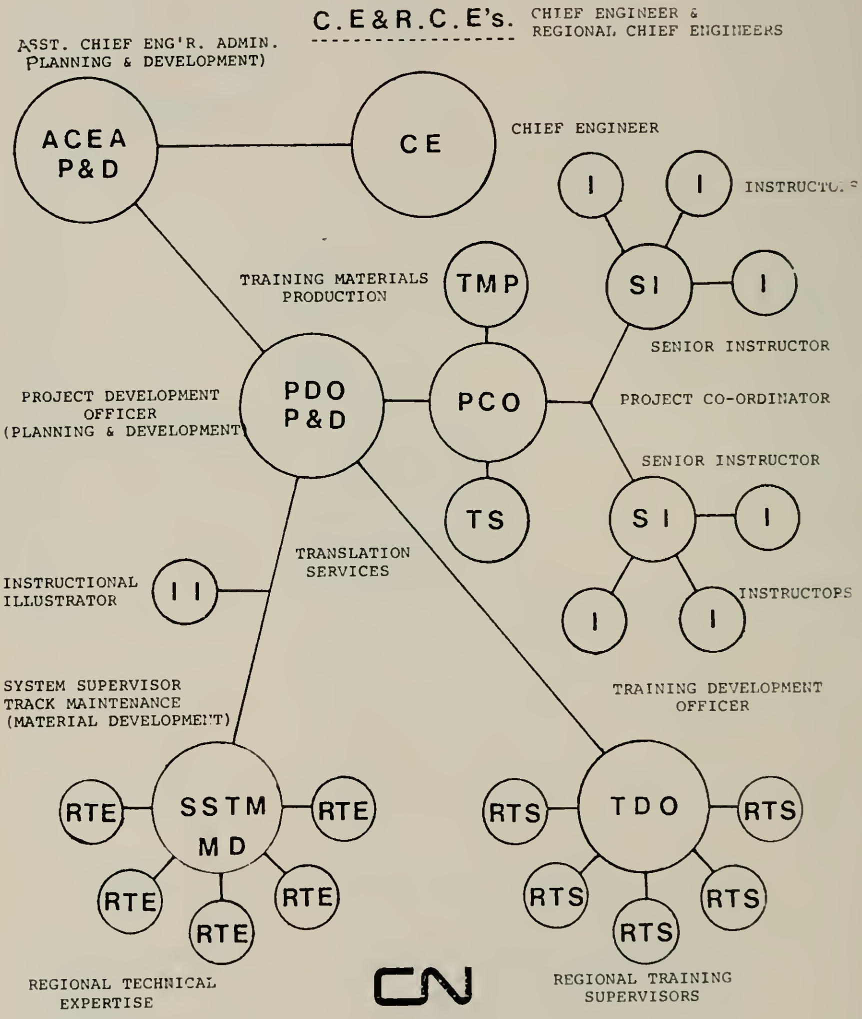

C.E&R.C.E's.
CHIEF ENGINEER & REGIONAL CHIEF ENGINEERS
ASST. CHIEF ENG'R. ADMIN. (PLANNING & DEVELOPMENT)
ACEA P&D
CE
CHIEF ENGINEER
I
I
INSTRUCTORS
TRAINING MATERIALS PRODUCTION
TMP
SI
I
SENIOR INSTRUCTOR
PROJECT DEVELOPMENT OFFICER (PLANNING & DEVELOPMENT)
PDO P&D
PCO
PROJECT CO-ORDINATOR
SENIOR INSTRUCTOR
TS
S I
I
TRANSLATION SERVICES
INSTRUCTIONAL ILLUSTRATOR
I I
I
I
INSTRUCTORS
SYSTEM SUPERVISOR TRACK MAINTENANCE (MATERIAL DEVELOPMENT)
TRAINING DEVELOPMENT OFFICER
RTE
SSTM MD
RTE
RTS
TDO
RTS
RTE
RTE
RTE
RTS
RTS
RTS
REGIONAL TECHNICAL EXPERTISE
CN
REGIONAL TRAINING SUPERVISORS

Fig. 2

COURSE	FOR	SCHOOL	TOTAL MODULES	MODULES READY	NUMBER OF WEEKS	REMARKS
TM-I	TRACK MAINTAINERS	REGION	15	14		FOR NEW MEN STARTS SEPT. 75
TM-I-A	TRACK MAINTAINERS	REGION	15	NIL		TO BE DEVELOPED
TM-II	FOREMEN REL. & ASST.	SYSTEM	19	19	3	2 INSTRUCTORS GOING NOW
TM-III	FOREMEN NEWLY APPOINTED FOREMEN ESTABLISHED FOREMEN NEED UPGRADING	SYSTEM	15	NIL		TO BE DEVELOPED
TM-IV	ROAD MASTERS POTENTIAL " " RELIEF " " ASSISTANT " " NEW RELIEF " " ESTABLISHED " " NEED UPGRADING	SYSTEM	23	23	2	GOING NOW
TM-IV-A	SAME AS ABOVE	SYSTEM	19	10		SEQUEL TO TM-IV
TM-V	ENGINEERS MTCE. ASST. ENGINEERS MTCE. TRACK SUPERVISOR AND POTENTIAL CANDIDATES	SYSTEM	21	21	1	INDOOR & WORKSHOP
TM-V-A	SAME AS ABOVE	SYSTEM	15	9		TO BE DEVELOPED SEQUEL TO TM-V
TM-VI	PROGRAM SUPERVISOR EXTRA GANG FOREMEN ASST. EXTRA GANG FOREMEN	SYSTEM	18	18		TO BE DEVELOPED
TM-VII	ROAD MASTERS SECTION FOREMEN	SYSTEM	15	4		TO BE DEVELOPED
TM-VIII	CONCERNED EMPLOYEES	SYSTEM	15	4		TO BE DEVELOPED

Fig. 3

TRACK MAINTENANCE TRAINING - PART IV (TM-IV)

TO BE CONDUCTED AT SYSTEM CENTRAL SCHOOL(S)
WITH THE EXCEPTION OF SPECIAL COURSES TO MEET LOCAL EXPEDIENCIES,
FOR POTENTIAL ROADMASTERS,
AND TO INCLUDE RELIEF,
ASSISTANT, NEW RELIEF, AND ESTABLISHED
ROADMASTERS WHO REQUIRE UPGRADING

NOTES	SUBJECTS
	1. JOB TRANSITION
	2. INSTALL AND ADJUST SWITCH POINTE
	3. INSTALL AND SWITCH STANDS
	4. PROPOSED DUTIES OF A ROADMASTER
	5. MAINTENANCE OF C.W.R.
	6. ROADMASTER'S CONTACTS
	7. RAIL JOINT MAINTENANCE
	8. GAUGING
	9. ORDERING OF WORK TRAINS
	10. MARKING TIES FOR RENEWAL
	11. MAKING A STOCK RAIL
	12. SHIMMING
	13. CURVES, SPIRALS AND SUPER-ELEVATION
	14. INSULATED JOINTS
	15. TRACK INSPECTION
	16. TURNOUT INSPECTION
	17. WIRE LINE INDICATOR
	18. SLOTTING OF RAIL JOINTS
	19. TRACK RECORDER CAR
	20. TROWELLING
	21. RAIL SAW AND DRILL
	22. SUMMARY
	23. 1009-B

Fig. 4-A

TRACK MAINTENANCE TRAINING - PART IV A (TM-IV A)

TO BE CONDUCTED AT SYSTEM CENTRAL SCHOOL(S)
AS A SEQUEL TO TM-IV.
TO INCLUDE RELIEF, ASSISTANT, NEW RELIEF
AND ESTABLISHED ROADMASTERS, AS WELL AS CANDIDATES
FOR THESE POSITIONS

NOTES	SUBJECTS
	1. PLANNING AND PROGRAMMING OF WORK
	2. ORGANIZING AND SUPERVISORY
	3. MAINTENANCE BUDGETS
	4. MAINTENANCE METHODS
	5. MACHINE APPRECIATION
	6. EFFECTIVE COMMUNICATIONS AND TRAINING
	7. DERAILMENTS (ROADMASTER'S ROLE)
	8. COST CONTROL
	9. LABOUR AGREEMENTS
	10. C. P. M.
	11. HANDLING OF DISCIPLINE
	12.
	13.
	14.
	15.
	16.
	17.
	18.

Fig. 4-B

The courses as they now are produced are created by a six-man committee headed by the above-mentioned system supervisor, assisted by our five regional inspectors, maintenance-of-way. This group meets two to three times per year, and among their other problems have accepted the challenge of producing basic lesson material. They review the current requests, review and agree on a previous set, and so on. It has become a continuing operation. As each set of requests comes through from the training group, each man returns to his home base with one assignment, gets it written ready for the next meeting, with its attendant review and eventual issuance as a TRAINING MODULE for use either at the schools or by roadmasters in the field. Care is taken to keep regional chief engineers and regional engineers maintenance-of-way aware of these modules as they are issued, but seldom are they challenged by this group.

At present we have eleven distinct training courses identified as shown on Fig. 3.

Roadmasters are also sent to a variety of other courses at various locations on the system. These courses are not particularly track-oriented, but in special cases the man is sent to either sharpen a talent or improve a weakness. Such courses as:

(a) Labor relations.

(b) Work study appreciation.

(c) Sensitivity courses (irreverently known as "charm courses") but having to do with effective management, how to handle people, improve production, etc.;

(d) And as previously mentioned, the School of Instructional Techniques.

(e) C.N. also encourages their personnel to improve themselves through correspondence schools, night schools and even university by paying half the cost of that education once it has been successfully completed.

The 23 modules which have been identified as being necessary for the roadmaster in TM IV, and the 11 in TM IV A are shown in Figs. 4-A and 4-B, respectively.

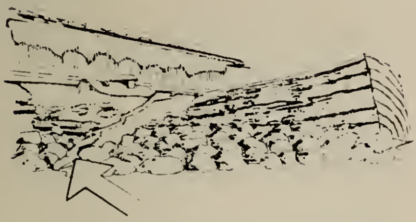
Shown below are data from Module No. 10—Marking Ties for Renewal.

MARKING TIES FOR RENEWAL

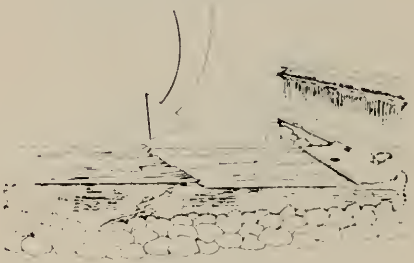
1. NO TIES EXCEPT THOSE MARKED FOR REMOVAL MAY BE REMOVED FROM TRACK.
2. BROKEN OR DAMAGED TIES MUST NOT BE REMOVED FROM TRACK UNLESS AUTHORIZED BY THE ROADMASTER.
3. THE ROADMASTER MUST PERSONALLY INSPECT TIES MARKED FOR REMOVAL.
4. GOOD JUDGEMENT AND COMMON SENSE IS NECESSARY WHEN MARKING TIES.
5. CONSIDER THE FUNCTION OF A CROSS TIE.
   A) THERE MUST BE SUFFICIENT TIMBER BETWEEN THE RAILS TO MAINTAIN GAUGE.
   B) THE TIE PLATE AND RAIL MUST BE SUPPORTED ON A FIRM BEARING.
   C) THE TIMBER MUST HOLD THE SPIKES TO PREVENT LATERAL MOVEMENT.
   D) THE TIE BOTTOM MUST TRANSMIT THE LOADING TO THE BALLAST.
6. CHECK CLOSELY IN THE TIE PLATE AREA FOR DEFECTS, USE A PROD IF NECESSARY.
7. OBSERVATION OF TIE ENDS GIVES CONSIDERABLE INDICATION AS TO THE CONDITION UNDER THE RAIL.
   A) CHECK TIES UNDER RAIL JOINTS TO ENSURE THERE IS SUFFICIENT SUPPORT.

TYPES OF DEFECTS TO LOOK FOR

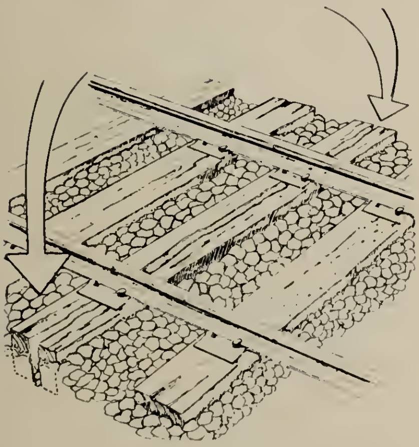
BROKEN TIE UNDER BASE OF RAIL.



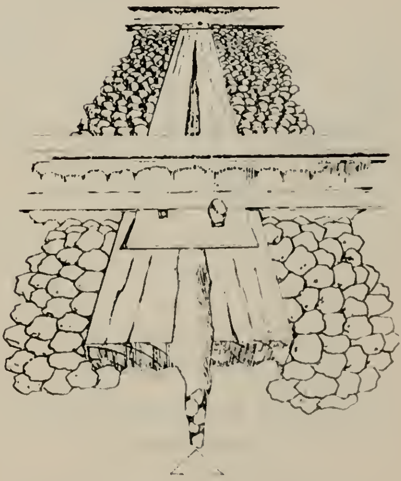
TIE BROKE IN CENTRE OF TRACK.



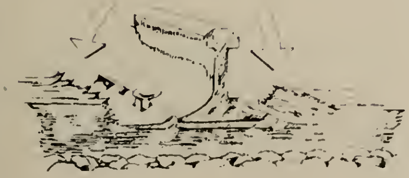
TIE SPLIT END TO END.



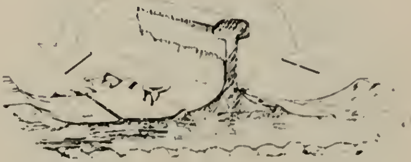
SPLIT TIE END.



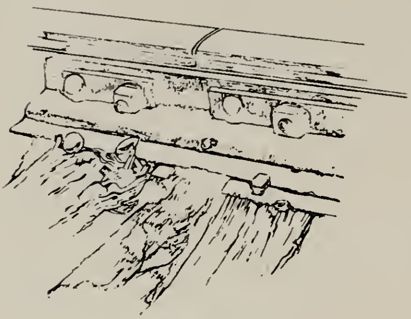
TIE CUT TO A DEPTH OF 2 INCHES.

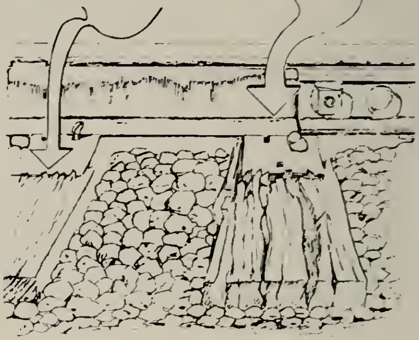


OTHERS ADZED TO A DEPTH
OF 2 INCHES.



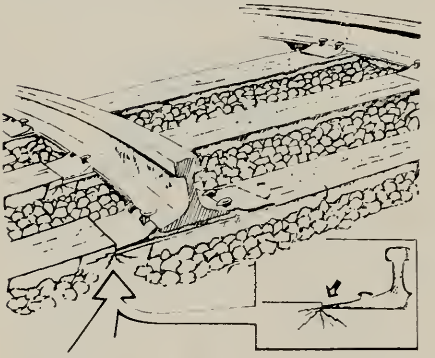
SPIKE KILLED, CRUSHED, AND DECAYED.



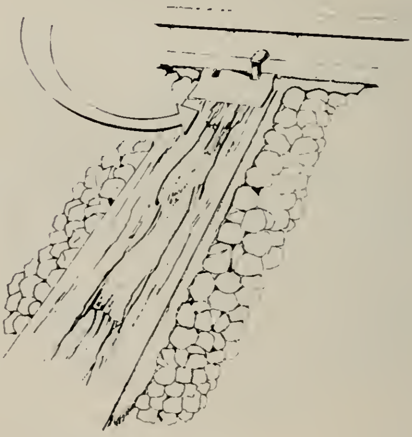


DECAYED TIE PROGRESSED UNDER THE TIE PLATE.

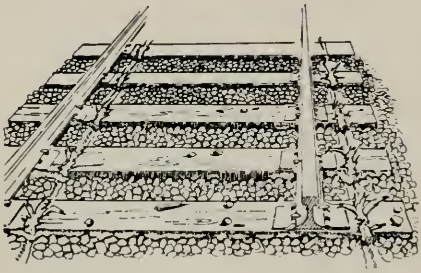
WIDE GAUGE



CUT TIE FIELD SIDE, CAUSING RAIL TO "CANT" OUTWARD.

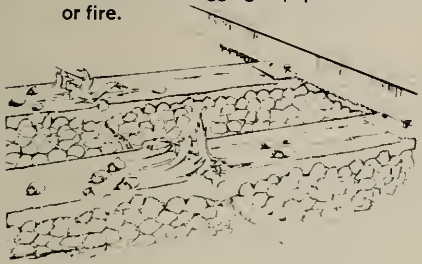


FLANGE CUT BY DERAILED WHEELS.

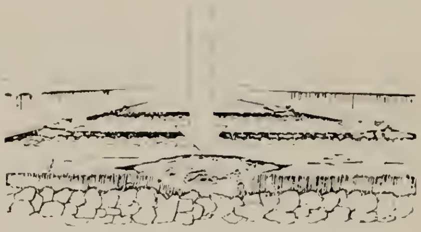


DAMAGED TIE

—Depth of 2 inches or more, due to derailments, dragging equipment or fire.



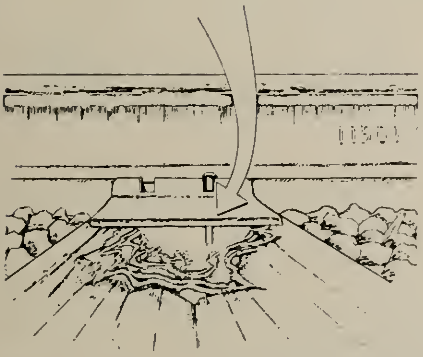
BURNT TIE



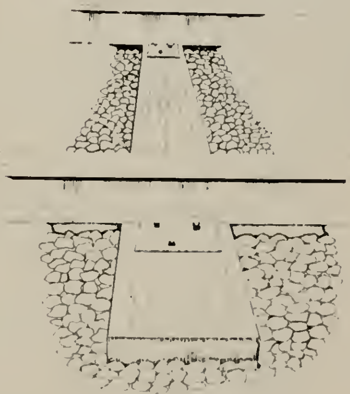
CHECK DEPTH OF BURN DAMAGE.

BURNT TIE

—Started by fusees, grass fires, or brake shoes.



GOOD TIE



WHEN SPOTTING TIES, TAKE INTO ACCOUNT THE CLASS OF TRACK.
—MAIN LINE, BRANCH, OR YARD TRACK.
—CURVED OR TANGENT.
—TONNAGE OF TRAINS.
—SPEED OF TRAINS.

Note that *safety* is not given a special category in our MODULES—rather, it is built into each module as it is issued. The teaching of operating rules is handled by the rules instructors of the operating department in a separate module.

There are many areas of concern to be kept in mind not only in choosing what is to be taught, but in the method of presentation:

(a) Educational levels and language comprehension vary. Keep presentations simple, use lots of sketches. Illustrations have a universal appeal and transcend education or language.

(b) Remember the trainees' backgrounds—main track vs. branch line, urban vs. bush.

(c) Variations in geography, weather, traffic have sometimes created the necessity for doing the same job different ways.

(d) Mountains, claybelts, permafrost, muskeg, narrow-gauge, and believe it or not, our "Castor Canadiensis," Canadian beaver, which messes up miles of drainage with its dams, have much to do with regional practices and traditions. Be ready to negotiate and/or compromise to a certain extent rather than calling the whole thing off, if standardization cannot be met.

Experience has shown us that the communication and commitment *must be "from the top down."* Officers and supervisors want to know what their men are being taught. Failure to ensure this communication will result only in a myriad of problems arising in the planning, development and implementation of each course which is put on. I cannot emphasize this aspect too strongly—neglect this most important step and you blow your training. Keep the credibility gap at zero!

Some other items may be of interest concerning our courses:

(a) The candidates are chosen at regional level, and with few exceptions, participation in the schools is voluntary. The men are not replaced on their regular jobs during training and there is no special item marked "Training" in the regional budgets.

(b) Courses vary in length from 3 days to 3 weeks, but a 40-hour week is maintained, with no night or week-end work. Neither is there any pre-course study material required.

(c) Don't use your training courses as a forum to weed out or separate the "promotables" from the others. We do not require "tests" or "examinations" as such. Rather, we use questionnaires—the purpose of which is to simply evaluate the effectiveness of the instruction, the material, and techniques. (See Fig. 5 for sample questionnaire.)

(d) We keep open communication with the Brotherhood in all our training activities and encourage them to visit our training schools as frequently as possible.

(e) A certificate (Fig. 6) showing that a man has undertaken a course is issued to each candidate. This certificate, believe me, vies for prominence with the first communion and marriage certificates in many homes, and graces the walls of many a toolhouse across the system. Additional seals may be placed on the certificate as the person progresses.

ROAD CROSSINGS - GENERAL

QUESTION:

1. ROADWAY OR VEHICULAR CROSSING APPROACHES SHALL BE MAINTAINED AS FOLLOWS:

ANSWER:

(A) TO AN UNEVEN GRADE HAVING IRREGULARITIES. ( )

(B) TO A SMOOTH AND EVEN GRADE WITH NO ABRUPT CHANGES. ( )

(C) TOLERANCE IN APPROACHES NOT GREATER THAN 3 INCHES. ( )

QUESTION:

2. A FLANGEWAY SPACE FOR THE CONSTRUCTION OF A NEW CROSSING SHALL BE:

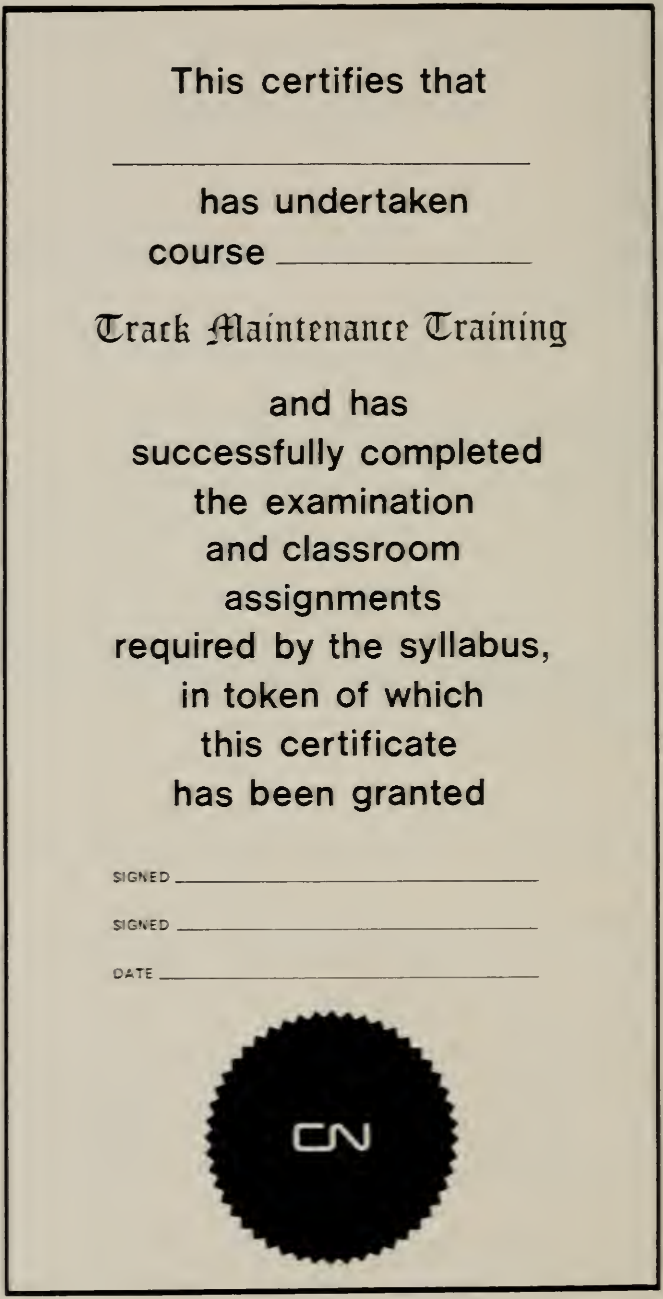
ANSWER:

(A) NOT MORE THAN 6 INCHES DEEP AND NOT LESS THAN 1 1/2 INCHES WIDE. ( )

(B) NOT MORE THAN 5 INCHES DEEP AND NOT LESS THAN 3 INCHES WIDE. ( )

(C) NOT MORE THAN 3 INCHES OR LESS THAN 1 7/8 INCHES DEEP, AND NOT LESS THAN 2 1/2 INCHES OR MORE THAN 4 3/4 INCHES WIDE. ( )

Fig. 5



This certifies that

____

has undertaken
course __________________

Track Maintenance Training

and has
successfully completed
the examination
and classroom
assignments
required by the syllabus,
in token of which
this certificate
has been granted

SIGNED ____________________________

SIGNED ____________________________

DATE ____________________________

CN

Fig. 6

Since our system-oriented schools are about one year old, we are presently unable to relate any specific improvement in our trackage; however, there are encouraging signs developing in the field among the men which, in time, will contribute to a better track. Initiative and self-confidence are becoming more evident, men are bidding and accepting promotions who have been reluctant to take responsibility in the past. There is a gradual swing toward an increase of efficiency and more attention is being paid to standards than ever before. The students who attend our schools are showing enthusiasm and motivation which was not previously evident.

And what of the future?

Manpower turnover, machinery development, traffic variations, re-organizations, Federal demands and the installation of the Metric System by 1980, are some of the variables which require us to be continually updating our MODULES.

We are embarking on the setting up of a bridges and structures training program, aimed at B. & S. foremen. Based on experience gained in setting up track training, our approach is more orderly and communication is better.

We are exploring the use of "FIELD-CLASSROOMS" situations where trainees could be placed to witness either planned or emergency situations which don't occur too frequently, nevertheless are real situations: derailments, landslides, washouts, pile-driving, wharf and ferry-slip maintenance, rock sheds, pipe-tunneling, etc.

We are also engaged in preparing what we call the "DAY-ONE-PACKAGE" and the "DAY-66-PACKAGE." The "DAY-ONE" will consist of information concerning the railway, organizations, chains of command, "stay-alive" rules, etc.; similar, but more detailed and expanded information concerning where the man fits into the organization, his possible career paths, training and education available, etc., will be in the "DAY-66 PACKAGE," so named because our probationary period for new employees is 65 days. Hopefully, this kind of treatment and communication will encourage young men *and women* to stay with us and make a career of railroading.

That concludes my presentation, gentlemen, and I would be pleased to answer any questions you may have. If there are those among you who would like to see our training at work, please contact me in Montreal at (514)–877–5093. We would be delighted to see you.

FRA, D&RGW, B&LE Joint Study of Track Geometry and Track Degradation

76–653–10

By B. H. PRICE
Senior Development Engineer
Bessemer & Lake Erie Railroad

For the past several years the Federal Railroad Administration, and two railroads, the Denver & Rio Grande Western and the Bessemer & Lake Erie, have engaged in a joint study of track geometry and track degradation.

The long-range objectives of this program are twofold. The first is to develop methods that can give quantitative ratings of track quality and therefore, by comparison, track degradation. The second objective is to utilize these methods to give a mathematical basis for long-range track maintenance planning.

The railroad-related benefits to be derived from such a program and the use of geometry measurement cars can be summarized as follows:

1. Increased accuracy in long-range maintenance planning.
2. Improved control of track department budget allocation.
3. Establishment of quality control measures of track work.
4. Improved track safety and inspection.
5. Documentation of compliance with FRA Track Safety Standards.

In addition, the program provides the government with the opportunity to test track geometry measurement equipment in the real railroad environment. Railroad personnel can evaluate the performance of that equipment and the validity of the data produced.

The key to such a program is the track geometry measurement car. The Federal Railroad Administration supplied this as a part of its contribution to the research. It also furnished, through a contractor, measurement car personnel, computer programming capability to handle the geometry data collected, computerized data reduction and reports, and the analytical techniques to evaluate the several methods suggested to rate track.

The two railroads involved furnished the locomotive power to handle the measurement cars on their property, crews to handle the measurement train, track for measurement and study, maintenance records of that track, and the railroad and maintenance of way expertise required for the project.

To power a typical FRA measurement train, a low-profile locomotive with the short hood forward is desirable, since it gives the observers in the cab the best view of the track ahead. The caboose is kept between the locomotive and the measurement cars so that the rear platform of the second car provides an unobstructed observation post.

The data measurement process is monitored on an 8-channel recorder. It simultaneously displays profile, alignment, cross level, curvature, gage and locations.

Note: Discussion open until October 15, 1975.

The bottom line is the event location trace. Mid-track anomalies, such as road crossings, turnouts, or location monuments are automatically sensed and accurately entered in the data stream by a detector located under the measurement car. Selected turnouts and road crossings have been established as reference locations and have been programmed into the computer as permanent stations.

It has been said that a picture is worth a thousand words. As a picture, the "squiggly" lines of the brush chart can be partially read and understood by track people. When the jagged line of the gage trace exceeds a given level, the roadmaster knows that he has a problem which must be examined in the field. Changes in the cross level or curvature traces can have some meaning to the experienced eye. Such defects as warp, even though they require the reading of only one trace, are difficult and time-consuming to detect. The meaningful comparison of one set of strip charts with previous ones of the same track is impractical.

To eliminate the need for a trackman to make extensive notes or to read the strip charts, a real-time, digital exception program and print-out is used. This provides him with a hard copy list of "critical" defects in profile, alignment, cross level, and gage which he can take with him when he leaves the measurement car.

Let me explain that a "critical" defect does not mean an immediate derailment, nor does it necessarily mean a violation of FRA Track Safety Standards. "Critical" defect levels were established by the chief engineer as a statement of minimum acceptable track quality.

The real time, digital print-outs are used by the track forces. There have been several occasions when a track supervisor, working from such a list, corrected all such defects before a formal list could be sent to him. On occasion, when data were lost by the computer, the track forces were able to locate and correct defects from these print-outs.

The earliest off-line defect report developed in the course of this project was the gage exception program. It located the beginning point of a defect, each change in the severity threshold, the maximum defect value recorded, and the end point of the defect. This could mean as many as eight to ten lines per defect and necessitated a report which ran for several hundred pages. The report showed defects only, with little or no effort to output gage quality.

In the early off-line profile exception reports, the exceptions were located and listed by defect magnitude. Stars denoted severity thresholds in ⅛-inch increments. The right-hand portion showed various profile quality rating techniques by rail. Many of these techniques will be discussed later in this presentation.

There were several drawbacks to this format. Since both the exceptions and the quality ratings were output as right or left rail, referenced to the measurement cars, it was necessary for the user to know the direction in which the train was moving when the measurements were taken. With both defects and quality ratings output in one report, the report was made unnecessarily lengthy. It also overlapped levels of user management. The supervisor was concerned with the defect portion. Generally the quality ratings had little value to him. The planner, who could best use these ratings, had no concern about the defects. They should have been corrected long before he reviewed the bulk of the data.

Currently these two exception programs have been replaced with the "Integrated Track Geometry Exception Report," shortened to "Ingrat." This report combines most of the parameter exceptions into one output and gives first-line supervision a comprehensive picture of track geometry defects.

On the left of the display is the location of the defect. Next the profile defects are shown, determined as the midordinate of a 14.5-ft chord. Now, however, they are identified as north rail or south rail, east rail or west rail.

Curvature exceptions are displayed in the next column. Because a single, isolated curvature data value cannot be considered a defect, but must be examined within the general context of the data values ahead and behind it, a special logic was developed for computer analysis. The values of the 60 data samples immediately preceding the sample point in question, as well as the 20 data samples immediately following, are averaged. If the value of the data sample in question varies more than a predetermined amount from this average, it is considered a defect.

Gage exceptions are shown in the next column, located near the center of the page. The maximum value of the defect is given as well as the overall defect length from threshold to threshold.

The next column shows cross level exceptions. They are not related to the FRA Track Safety Standards nor are they related to curvature. These cross level defects are computed using the same averaging technique as used to determine curvature defects. In this program a half-mile tangent with a uniform 1 inch or 1½ inches elevation would not be processed as an exception.

Warp is defined as the rate of change of cross level. It is determined from the absolute cross level values, and, in this program, computed over a 31-ft distance.

Rock-and-roll is the last geometry value output in the Integrated Exception Report. It is defined as the magnitude of change of direction of cross level over a specified distance, in this example 19½ ft.

The Integrated Exception Report provides the trackman with a comprehensive display of much of the data needed to repair defects in the track. It is based on "critical" defect levels and has little correlation to the track safety standards.

The "critical" defect can never be ignored. It must be identified and corrected for the future safety of the trains. But what about the larger percentage of the track which contains no "critical" defects? Here middle management is concerned with the trends which can indicate the quality of maintenance work recently completed, or the nature of work which may be required in the future.

A number of methods have been developed and are being studied for rating profile quality. Several of these are already being output in summary form for quarter-mile sections of track. The location of the section is shown on the left. Then the various rating values are displayed.

The quarter-mile section was selected for several reasons. While one can argue that tangents and curves should be separated, neither a measurement car nor an experienced surveyor can accurately locate a point of curve to the nearest foot on the track. Some sort of permanent monument would be required at each end of each curve as an absolute minimum. The FRA measurement car can measure a mile of track with a maximum of error of 5 ft (0.1 percent). The computer can accurately divide this mile into quarters. By selecting turnouts and road crossings located generally 3 to 5 miles apart as permanent monuments, highly repeatable quarter-mile sections can be output for each test run. At the same time, these sections are then short enough that limited changes in the data do not become masked by the sheer mass of data.

One of the most promising rating methods is the profile "index" value. It is defined as the area between the measured profile data curve and theoretically perfect track. It is measured in square inches over a quarter-mile section.

Such profile index values generally range from a minimum of 600 square inches per quarter-mile to 2,000 square inches per quarter-mile when the track is laid with CWR. On bolted rail on branch lines it can go as high as 3,000 square inches per quarter-mile of track.

A list of the quarter-miles of track with the highest index values is given to the track department in the fall. This list is designed to inform them of the worst short sections of track so that surface repairs can be made before the winter freeze sets in.

The index value has also been found to be informative in other ways. A measurement run was made on the Hilliards Branch in the fall and again in the following spring. Between runs the track was raised and lined from Mile Post 5 to Hilliards. Changes in the computed index value show expected deterioration between Mile Post 1 and Mile Post 5. From Mile Post 5 to Hilliards most of the miles show a definite improvement. However, between Mile Post H-6 and Mile Post H-7 the track profile seems to have become rougher, even though it had been raised.

A discussion with the supervisor track for this territory developed that surfacing actually began near Mile Post H-6 with the gang working toward Hilliards. This was the first use of the tamper since its winter overhaul, and "bugs" developed in its electrical system. For the first several days of surfacing, production was low and the machine had a tendency to hump, or over-raise, the track. The problem was corrected by the time the gang passed Mile Post H-7.

A second profile rating value being investigated has been termed "cumulative slope." To define this graphically, the cumulative histogram of all the profile data points is constructed. Mathematically the slope of a line is described as the tangent function which is equal to "delta" Y divided by "delta" X. By reading across the graph, at the 70 percentile level, and at the 30 percentile level, the corresponding profile values can be determined. The change in "Y" values is 70 percent minus 30 percent. The change in "X" is the algebraic difference of the two "X" axis readings. By division, then, the slope value can be calculated. If the track section is smooth, the data points will tend to group tightly together; delta X will tend to be smaller and the slope value will tend to be larger.

The profile index values and the profile slope values tell an almost identical story.

These rating methods are concerned with the overall condition of a quarter-mile section of track. However, it is possible that only a few isolated spots may begin to deteriorate. The 0.5 percent value is an attempt to measure this type of change. It can be described as that value of the data which is less than 99.5 percent of all the values in the section.

The figure shows the lower end of the cumulative distribution curve, with the cumulative percentage of the data as the ordinate and the profile value as the abscissa. The computer, in effect, reads up to the 0.5 percentile level and then over to the curve to find an intercept value.

These two gage traces (not reproduced herein) represent a section of track measured 18 months apart. A close comparison of the left half of the two traces shows that gage is widening. The same trend can be seen by comparison of the extreme right-hand portions.

The gage is "worse." But how much worse? There are four or five spots which read about 57.50 inches—or 1 inch wide. One spot appears to be 1¼ inches wide. A track gang can be sent out to locate and repair these spots, but the traces can tell little else but what is interpreted by "operator judgment."

This slide (not reproduced herein) shows an attempt to quantify gage, to give it a meaningful numerical value. The track has been divided into consecutive quarter-mile sections. Each quarter-mile section normally contains 546 samples of data. On the left of the slide the track section is identified by location of its end point. In the third column the arithmetic mean of all the gage data points in that quarter-mile section is shown. The next column shows the statistical variance or distribution of the data points about the mean. The right-hand group of columns indicates the percent of the data points falling within a given level of gage.

Unfortunately, difficulties with the capacitive gage measurement system have hindered the development of gage rating techniques. At first "mean" gage appeared to be a promising rating value, but after two years of experience, analysis, and field checking it was found that the measurement system could not repeat gage accurately enough from year to year to allow for comparisons.

Calibration errors, weather effects, lipped or worn rail, and the nonlinearity of the voltage-gap curve in the amplifiers can give a probability of error in gage readings greater than the actual change in gage in the course of the year. This is not to say that the absolute value output for a gage defect is not valid. In reality it is. Experience over the last three years has shown that virtually all of the defects reported are real.

For comparative purposes, gage "variance" has proved to be a more meaningful indicator of a general change in gage. Since it is a measure of the variation from average gage, it is not nearly so sensitive to calibration errors.

Use of percentage level rating technique for gage has been hampered by the same instrumentation problems that developed in the attempts to apply "mean" gage for comparative purposes. However, the calibration oriented shifts are somewhat more apparent in the percentage level technique.

Pictorial representations of the data can be made through the use of the histogram. The computer plots the percent of data points, shown on the "Y" axis, against the data values, shown on the "X" axis. For quarter-mile sections, this is a cumbersome technique, but for longer stretches of track, it can be very useful to display information.

Comparisons can be displayed between two sets of data by denoting one set with the numeral "1", the second set at numeral "2", and common points with dots.

Some of the problems related to the development of gage rating techniques will not be solved until the all-weather gage system is installed and field tested.

Many track geometry defects are the result of an improper relation between curvature and superelevation. With the development of the curvature measurement system, it became possible to write a curvature-cross level analysis report. This is not strictly a defect type report. The left third of the figure locates and describes the various elements of the curve without regard for defects. The right-hand two-thirds is a defect report. Errors in matching cross level and curvature are noted.

These can occur at the tangent end of the receiving or leaving spiral when curvature and superelevation do not begin or end at the same point. This mismatch can also occur at either end of the body of the curve when full curvature and full elevation do not coincide.

Reverse cross level can be found in the tangent just ahead of the spiral, or in the body of the curve, if the cross level actually goes negative (with respect to the superelevation of the curve).

Curvature defects are computed as previously discussed, but because cross level and curvature are combined in the program, an allowable speed can now be calculated for the defect. This speed is based on the formula in the FRA track standards.

Cross level defects, warp defects, and rock-and-roll defects have already been discussed. But, now cross level in tangents can be determined. Spirals can be delineated and multi-level standards can be used in tangent as opposed to curves. More data can be output in terms of the track standards, if this is the desire of the user.

In practice, there are probably three general levels of management to which track geometry data reports should be directed. The first level is primarily concerned with defects. Middle management is more concerned with the general quality of the track and the changes taking place in that quality. Upper management needs a report that can give a clear and concise picture of the condition of the track and changes in that condition.

GEOPOT was developed for use by the latter two groups. An example (not reproduced herein) gives a three-year (or a three successive measurement run) quality rating comparison of gage, profile, cross level, and curvature. The ratings are displayed by miles, with approximately 30 miles of track being displayed on one page of computer print-out.

In order to output such a program, it was necessary to have quality rating values for each of the four parameters. Variance, or standard deviation, was already available as a rating of gage. Track index had been developed as a rating of profile.

By applying the same general concept that is used to compute the profile index, cross level and curvature index values were programmed. In profile index the actual data sample value is compared to theoretically perfect track. In cross level and curvature indices, the actual data sample value is compared to an average value.

To date, the exception reports have been used to correct gage defects after each measurement run. They have also been used for several years to maintain safe gage on a light traffic branch line even though a tie deterioration problem is developing. The gage and profile reports have been used to assist in the upgrading of another branch line for anticipated heavy tonnage increases.

It has been possible to show progressive gage widening in a few isolated curves by comparing gage rating values over a period of several years. In this process there have developed indications that the mechanized tie gang may, in some cases, actually contribute to long-range gage widening.

More progress has been made in the rating of track profile than in any other parameter. As mentioned before, profile index values are in actual use today.

To date, profile defect and rating data have been developed by the capacitive sensor chord system. Thus it is not compatible with FRA standards. Because the profilometer can output data in terms of any chord length, including the FRA track standards, it was selected to replace the capacitive chord profile system. To date it appears that the profilometer is speed sensitive. However, recent tests indicate an early solution can be expected, and a major effort is being directed toward correcting the problem. Once profilometer accuracy has been demonstrated, plans call for developing profile data from this system.

At present the severe defects in cross level, warp, rock-and-roll, and curvature are taken from the Curvature Analysis Report and checked in the field. Corrections are then made by the track forces. Experience has shown that the reported defects are valid imperfections that need attention. Even though the raw data were taken under load, a large majority of the defects can actually be seen by eye in the field if the investigator knows where to look. However, a track inspector might normally pass over many of them.

Aside from the cross level and curvature "index" values used to develop GEOPLOT, no rating values for these parameters have yet been devised. Cross level and curvature "index" values have yet to be verified and significant values of change determined. There has been no effort to output these values for the quarter-mile track sections for comparative purposes. This effort will be a future project.

But a number of valuable observations have already been made from curvature and cross level data. Instances of cross level in tangents, while not of sufficient magnitude to be safety standard violations, indicate that the quality of production tamper raising may not be as good as has been assumed. This may be the result of equipment weakness, human failure, or both. Swings of up to 1½ degrees with a definite periodic frequency have been found in isolated curves. Here the maintenance officers would not believe that they existed until a set of stringline notes proved otherwise. This condition appears to have been the result of curve deterioration resulting from traffic.

A study of the matching of superelevation with curvature, particularly in the spirals, indicates that raising and lining techniques need some improvement. The point of full elevation often does not match the point of full curvature. The beginning point of the spiral does not always match the point of zero cross level, yet generally the spiral curve is smooth and the superelevation runout is uniform.

The GEOPLOT program appears to be a very useful summary. The indices are based on statistical values which are relatively insensitive to possible instrument error. Since large-scale maintenance programs are planned for at least one mile of track, any errors in distance measurement would not be great enough to create a serious comparison problem. It gives a snapshot summary of the major parameters to the maintenance planning engineer.

I regret that I have not been able to give you more detail in this brief overview of our cooperative effort. However, I am happy to announce that a publication on the project is available on the back table for those who wish to take a copy as they leave the sessions.

In the past three years we have learned a great deal about instrumentation, report generation, and track geometry. We have also developed a great respect for the geometry measurement system. There is much more still to be learned and this project will be continued.

I should point out in closing that any of the programs or instrumentation developed in this effort are public property and information concerning them can be obtained from FRA.

Track Geometry Car—Management Usage

76–653–11

By R. W. HOLT
Director, Road Maintenance Management Systems
Canadian Pacific Limited

Canadian Pacific Railway has been operating a Track Geometry Car* on its lines for approximately three years. For this period of time, our systems staff have emphasized the field use of the car, and most of the development work in terms of reports and procedures has been geared to use by roadmasters and division engineers. To this end we have been successful, and find that the car and the resulting reports are well accepted by line management. This success is due in part, I feel, to our policy of providing information that has actual meaning to lower management levels, such as the roadmaster. As an example of this policy, we indicate such items as the average drop in joints, given in inches, rather than a statistical index number indicating the relative condition. Whereas in theory the two types of information are identical, the one is presented in terms more familiar to the field. This policy, coupled with our philosophy that the primary purpose of the car is to assist the roadmaster and division engineer in their duties, has brought us to the point today where we feel the car is operating successfully as a field management tool.

With this confidence in our success to date, we are now looking to the area of middle and senior management use of Track Geometry Car information, and we are currently working on development of several new reports intended to complement medium to long-range planning. I have prepared eleven visuals: the first three show reports currently being produced from our car; the next three show the reports which are presently under development, and the last five display some ideas we are considering for future use of the Track Geometry Car.

FIGURE 1

This first illustration shows one of the two reports presently being produced on board our Track Geometry Car. This report indicates the condition of the combined rail profile, and also the track gauge. For each quarter mile, the number of surface defects encountered between ¼ and ½ inch, ½ and ¾ inch, and over ¾ inch, are shown. These defects, of course, are primarily low joints, although any "dip" in either rail of at least ¼ inch will be shown. For gauge, we show the number of linear feet of over-gauge, for ½ to ¾ inch, and over ¾ inch, wide gauge. Along with the measurement of gauge feet is the number of occurrences which made up the given total feet. We show the number of occurrences to distinguish, for example, between a quarter mile of track with one stretch of 100 ft wide gauge, versus say 20 locations in the quarter mile with an average of 5 ft over-gauge each, also making 100 ft.

---

* The term "Track Geometry Car" is used herein because it is more familiar to the intended readers. Canadian Pacific's car is actually named the "Track Recording Car," and the two terms should be considered synonymous

Note: Discussion open until October 15, 1975.

	SURFACE DEFECTS			OVER-GAUGE	
MILEAGE	1/4 1/2	1/2 3/4	3/4 +	1/2 3/4 (FT/OCC)	3/4 + (FT/OCC)
1.00					
1.25	28	7	0	0/0	0/0
1.50	27	8	0	0/0	0/0
1.75 M	29	9	1	0/0	0/0
2.00 M	23	1	0	0/0	0/0
2.25	32	9	1	0/0	0/0
2.50	28	7	0	12/2	0/0
2.75 S	21	3	0	487/27	0/0
3.00 S	37	13	4	12/1	0/0
3.25	29	3	0	0/0	0/0
3.50	23	6	0	1/0	0/0
3.75	28	7	3	38/4	0/0
4.00	25	5	1	345/26	162/6
4.25	25	3	0	0/0	0/0
AVERAGE	27	6	1	69/5	12/0

Fig. 1

This report is read as follows: between Mile 1.00 and 1.25, there are 28 joints dropped in the range of ¼ to ½ inch, 7 joints in the range of ½ to ¾ inch, and there are no joints which have dropped more than ¾ inch. There is no wide gauge on that quarter mile. The report is taken by the roadmaster, and is used to highlight those areas of track requiring attention during regular maintenance activities.

FIGURE 2

This report (Figure 2) is actually produced alongside the previous one, on the same printer on the car. It shows the location of priority defects. At present, we isolate five types of priority defects which, by definition, require special attention on the part of the roadmaster. These five types are:

(a) Rock-and-Roll, defined as six or more consecutive joints on 39-ft rail, (i.e., three joints on each rail) which have dropped over ⅝ inch each.

PRIORITY DEFECTS

FROM MILEAGE FT.	TO MILEAGE FT.	RR	SL 1+	SR 1+	CL 1+ IN. 11 FT.	GAUGE 3/4 + (FT/OCC)	
	2.0 +128	0	0	0	1	0/0	
	2.0 +326	0	0	0	1	0/0	****
	2.1 +267	0	1	0	0	0/0	
3.1 + 79	3.1 +313	6	0	0	0	0/0	
	3.1 +425	0	0	1	0	0/0	****
3.5 +128	3.6 + 79	0	1	2	1	0/0	****
3.6 +111	3.6 +462	9	0	0	0	0/0	
	3.7 +428	0	0	0	0	12/1	
	3.8 +178	0	0	0	0	21/1	****
3.8 +206	3.9 +326	0	0	0	0	129/4	
TOTAL		15	2	3	3	162/6	

```
****************************************
*                                      *
*  NOTE: THERE ARE ONE OR MORE URGENT  *
*        PRIORITY DEFECTS REQUIRING    *
*        IMMEDIATE ACTION.  THESE ARE  *
*        HIGHLIGHTED ABOVE BY FOUR     *
*        (4) ASTERISKS (****).         *
*                                      *
****************************************
```

Fig. 2

(b) Surface Roughness, Left Rail, and
(c) Surface Roughness, Right Rail, isolating any joint which has dropped over 1 inch
(d) Cross-level, where the rate of change in cross level is greater than a slope of 1 inch in 11 ft, and
(e) Gauge, isolating any location with wide gauge in excess of ¾ inch.

Each time one of these priority defects is recognized, a message giving the location to the nearest foot is printed. If the printer gets "too busy," however, a few priority defects will be summarized. Any of these messages followed by four asterisks indicates an urgent priority defect, representing a serious condition which must be attended to immediately.

This report is read as follows: at 128 ft past Mile 2.0, there is a priority cross-level error; at 326 ft past Mile 2.0, there is another cross-level error, requiring urgent action; at 267 ft past Mile 2.1 there is a joint in the left rail which has dropped more than 1 inch, and so on. Our experience to date is that the roadmaster will have little difficulty in locating each of these defects.

FIGURE 3

This graph is produced on our headquarters computer from data stored on magnetic tape on board the Track Geometry Car. Each vertical line represents the

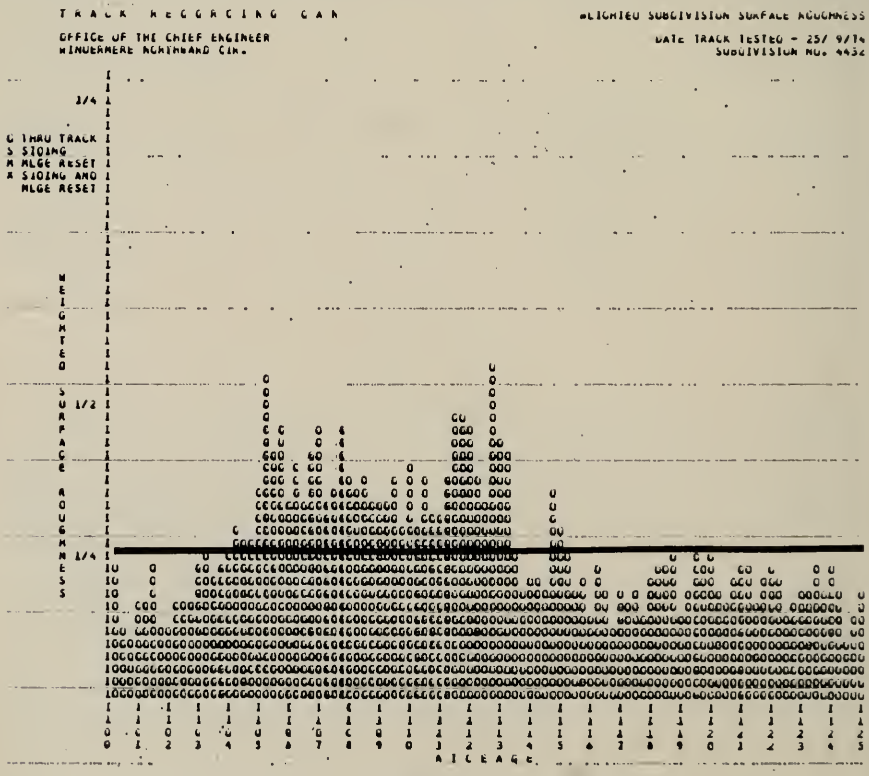


Fig. 3

surface roughness condition (both rails combined) for a quarter-mile section of track. This particular graph shows a section of our Windermere Subdivision in the Rocky Mountains, between Mile 100 and Mile 125. The abscissa of the graph shows the mileages, the ordinate shows the relative joint condition for a reference stretch of 39-ft rail. If the average drop in the joints is comparable to an average drop of ¼ inch per joint in standard 39-ft rail, the vertical line would come up to the ¼ inch point on the graph ordinate, as shown by the position of the bold horizontal line. A weighting factor is applied during the calculations, so that the vertical lines on the graph rise rapidly with worsening conditions.

This graph is used for such things as the setting of surfacing programs. If we set a standard of ¼ inch average joint drop, as represented by the bold line, then this graph shows that some surfacing work should be carried out between Mile 104.25 and 115.25. We intend to produce the same type of graph for gauge, cross-level, superelevation and alignment measurements.

The next three illustrations show reports which are presently under development.

FIGURE 4

This graph, which will be produced by our headquarters computer on a plotter, shows the relative condition of the rail profile for tests taken at three different periods of time. My sample here shows the first 56.2 miles of the "Holt Subdivision" and the data are entirely fictitious. The vertical scale of the graph shows the relative number of joints per mile, based on 39-ft jointed track. The graph abscissa shows rail surface defects ranging from ¼ inch to 1½ inches.

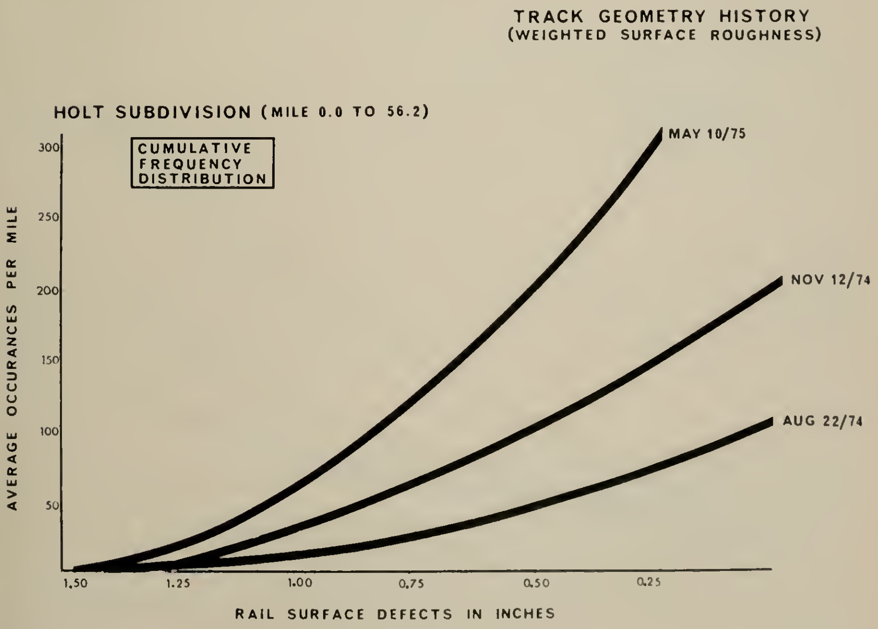


Fig. 4

As a general rule, the lower the line is on the graph, the better the surface roughness condition. Furthermore, the more the line "stays away" from that left-hand side of the graph, the less the incidence of potentially serious conditions. For the purposes of illustration, this graph shows a very marked deterioration of track between August 22, 1974, where the condition was relatively good, to May 10, 1975, where the track is in very serious need of maintenance.

This graph will be produced separately for each of the measurements taken by the Track Geometry Car. It is intended for medium range planning by middle managers. I say medium range, because there is one element of data which affects the deterioration of track as it is displayed here, and that is the time of year the tests are taken. On our example here, the May 10 line represents a test at the height of our spring thaw, and any attempt to project the rate of deterioration here over a long period of time would lead to false conclusions. For such long-range projections, we need to compare track conditions taken over several years at approximately the same time of year.

FIGURE 5

This graph is identical to the previous one, except that the tests were taken at the same time of year. We now have information that may be projected over a longer period of time, providing there is an understanding of the work carried out on the track during the time frame displayed.

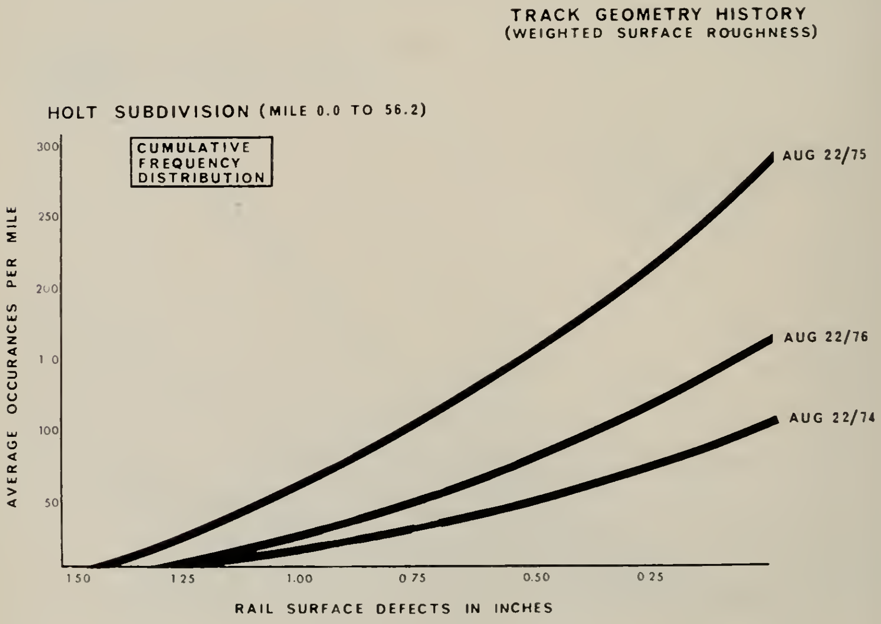


Fig. 5

SUBDIVISION TRACK RATINGS

	SURFACE ROUGHNESS	GAUGE	CROSS LEVEL	ALIGN	SUPER ELEV	WEIGHTED TRK CONDITION		
						MAR 1/75	MAR 1/74	5-YR AVE
McADAM	56	22	44	8.9	10.3	278	224	235
ADIRONDACK	38	19	29	4.6	8.2	261	195	204
THREE RIVERS	43	15	35	6.3	8.1	235	189	199
BELLEVILLE	71	26	42	10.8	17.6	324	278	291
GALT	69	21	37	7.5	14.9	286	250	267
CARTIER	82	28	52	11.1	18.9	332	311	323
IGNACE	75	23	48	10.0	15.5	309	287	298
CARBERRY	54	17	31	7.9	12.8	273	242	252
INDIAN HEAD	37	11	20	4.4	7.4	221	169	186
LEDUC	36	18	27	3.9	8.0	258	179	189
MOUNTAIN	83	24	43	11.2	18.7	337	289	309
CASCADE	39	21	30	4.2	8.4	264	183	195

Fig. 6

FIGURE 6

I have stressed, so far, our attempts to keep the elements of information meaningful. You may also have noticed that I have not in any case combined the various measurements, as for example in the graphs, where there is a separate graph for each measurement taken by the car. With this illustration, however, I am about to break both of those rules. Here we shall calculate a relative index number to show the overall condition of surface roughness, gauge, etc., on each Subdivision. We shall then apply weighting factors to each of these conditions, and develop an overall track condition figure for the Subdivision. This figure is shown for the current year, the previous year, and as a five-year average.

I would not be honest with you if I did not tell you that I am somewhat cautious of this type of information. I do not feel that meaningful conclusions can be made directly from information summarized to this extent. This report will be used only by senior management, and it should be considered a barometer which indicates problem areas. As such, this report is a reference only, and should trigger a further request for more detailed information.

FIGURE 7

The following five figures display ideas that we are presently considering for future development in the use of the Track Geometry Car. As I am sure you are already aware, it is possible to remove the actual measurement devices from the trucks of the Track Geometry Car, and install them on the trucks of another car. Cables are then run back to the Track Geometry Car to the various electronic equipment. The idea, of course, is to measure track conditions under a different loading pattern, such as the 100-ton coal car shown in Figure 7. Certainly one would not expect the track to react the same under this 132-gross-ton 4-axle car as it does

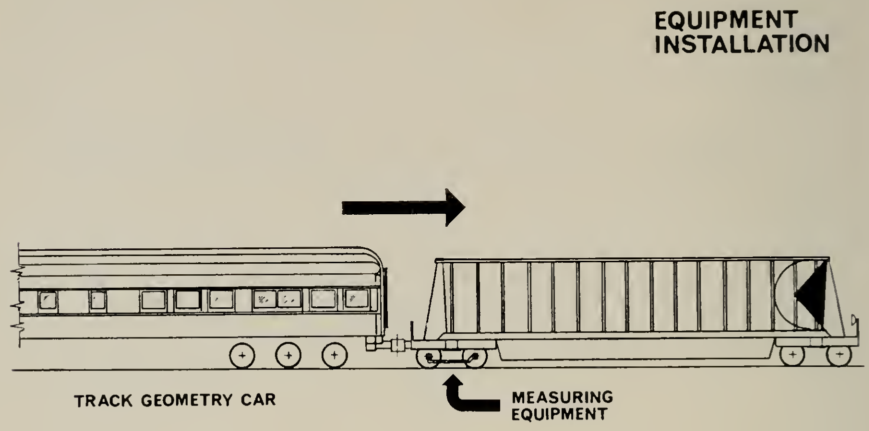


Fig. 7

under the 125-gross-ton 6-axle Track Geometry Car, with its special suspension. If one wanted a true indication, for instance, on the effect on track of running unit coal trains, it might be interesting to measure a section of track under a standard box car, and then re-run the same section of track under the heavy coal car. We estimate two to three days time to set up each such special test, and hope to attempt it sometime in the future.

FIGURE 8

At Canadian Pacific, I am personally involved with a group called "Road Maintenance Management Systems." Our primary objective is to develop an overall information system for road maintenance management and, once created, to supply management support in analyzing the data collected. The information system will include a full inventory of the roadway, such as rail, ties, ballast and subgrade, as shown here. Also included will be operating information, such as number of trains, gross tonnages, axle loadings, and train speeds. Keeping the operating information current will be relatively simple, because the information is already available through Accounting and Transportation sources. Creating the initial track inventory is also simple conceptually, although very time-consuming. Such an inventory, however, must also reflect the condition of track, as well as the physical components which make up the track. It is in this area that the Track Geometry Car will be used to constantly update the inventory on track condition.

All these data, along with the resources available in terms of money, and labor, must be analyzed in order to make meaningful maintenance of way decisions. As vice chairman of the American Railway Engineering Association's Committee 32—Systems Engineering, I am often asked to define a "system." Figure 8 depicts a system, and to analyze that system we must consider all of its components together. The result of these analyses should be improved maintenance of way policies.

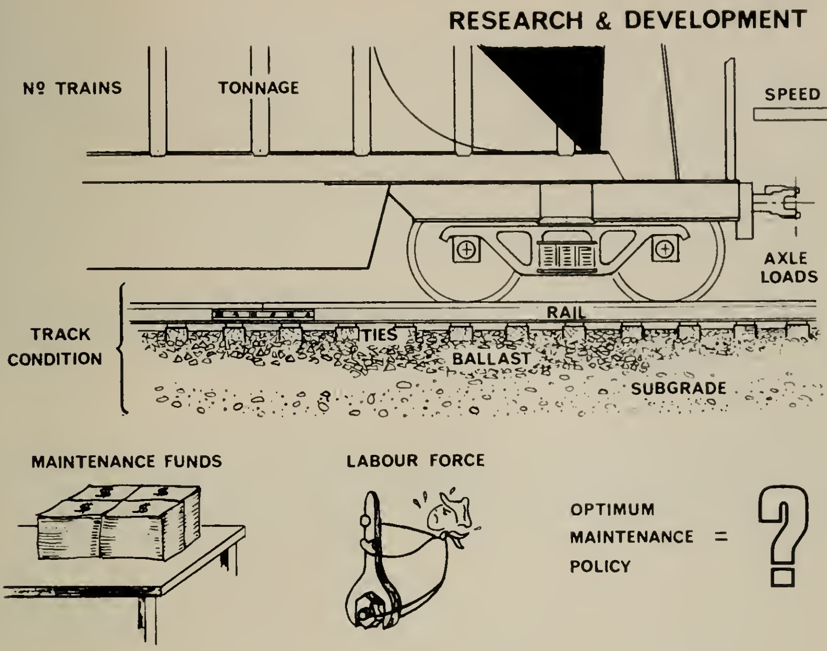
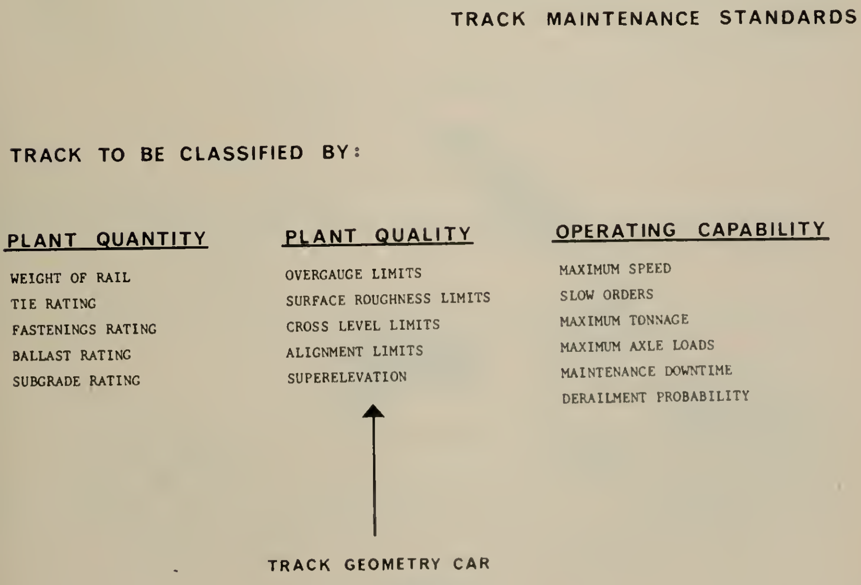


Fig. 8



TRACK MAINTENANCE STANDARDS

TRACK TO BE CLASSIFIED BY:

PLANT QUANTITY

WEIGHT OF RAIL
TIE RATING
FASTENINGS RATING
BALLAST RATING
SUBGRADE RATING

PLANT QUALITY

OVERGAUGE LIMITS
SURFACE ROUGHNESS LIMITS
CROSS LEVEL LIMITS
ALIGNMENT LIMITS
SUPERELEVATION

OPERATING CAPABILITY

MAXIMUM SPEED
SLOW ORDERS
MAXIMUM TONNAGE
MAXIMUM AXLE LOADS
MAINTENANCE DOWNTIME
DERAILMENT PROBABILITY

TRACK GEOMETRY CAR

Fig. 9

FIGURE 9

One of the objectives of our Road Maintenance Management System is the setting of track maintenance standards. I use this term as being something quite distinct from track safety standards. In developing maintenance standards, we are looking for an efficient trade-off between minimizing roadway maintenance and capital expenditures, and maximizing desired operating capabilities. The items to be used in setting these standards, as shown here, are only examples. We shall have to complete our analysis of the system depicted on the previous figure before we can say with certainty what elements should be considered, and what the limits should be.

I wish to emphasize here, however, the importance of the Track Geometry Car in the development of these standards, and in monitoring their application. The car will be indispensible in providing the information on plant quality necessary to make the standards work.

FIGURE 10

I mentioned above that we at Canadian Pacific are presently developing a computerized inventory of track, as part of our Road Maintenance Management System. Certainly this inventory will have to contain track profile data, and we are confronted with a major effort of manually coding all the grades and curvature

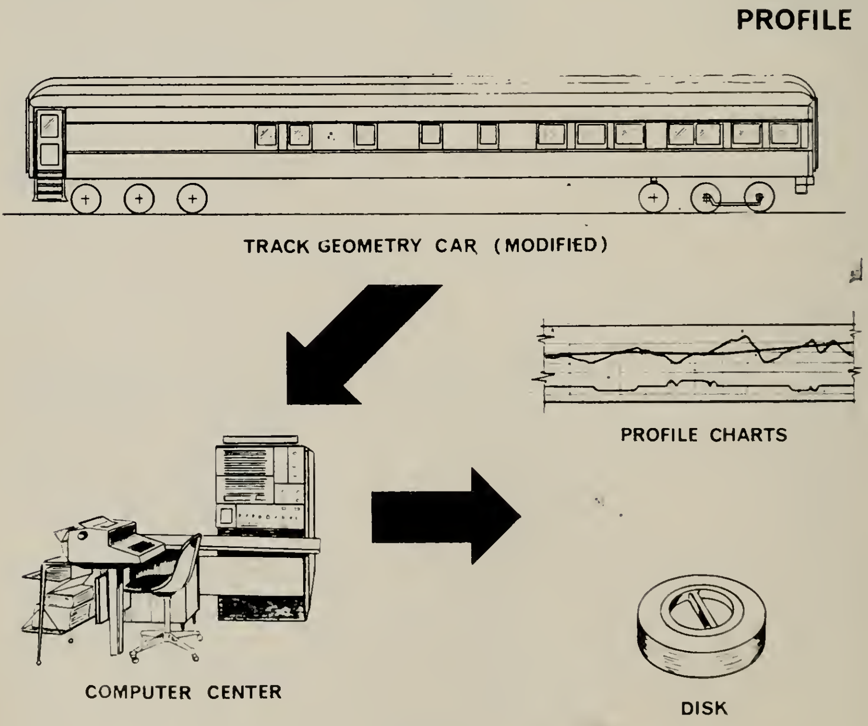


Fig. 10

on our 17,000 miles of track. Furthermore, we are not certain of the validity of the existing profile charts which would be used.

As an alternative, we plan to modify our Track Geometry Car for a special "one shot" run, to measure grade and curvature. Actually, the car measures curvature today, and we shall shortly be undertaking a study with Canadian National Railways into the development of a reliable and accurate grade measurement device. Once complete, all grade and curvature data will be stored on magnetic tape on the car, and transferred to our headquarters computer, where the data will be automatically stored as part of the track inventory on computer disk. There will also be a plotter connected to the computer, which we shall use to mechanically produce an entire set of profile charts to replace our existing charts. The final result will be, therefore, a partial re-survey of the railway using the Track Geometry Car, at a cost that must be considered negligible when compared to conventional surveying costs.

FIGURE 11

This final illustration displays another idea we are presently working on, in conjunction with the Canadian National. The line 1A shows the type of signal the Track Geometry Car produces for surface roughness. The two "dips" in the line are rail joints. The computer on board the car monitors this signal, and locates the high and low points on the line, as shown by the line 1B, where we now have isolated the low spot at the small arrow, which is the joint, and the high spots on either side. These points are used in calculating the actual drop in the joint. What I wish to impress on you here is how much the data is summarized: we started with the line 1A as a continuous signal, which possesses an infinite number of points

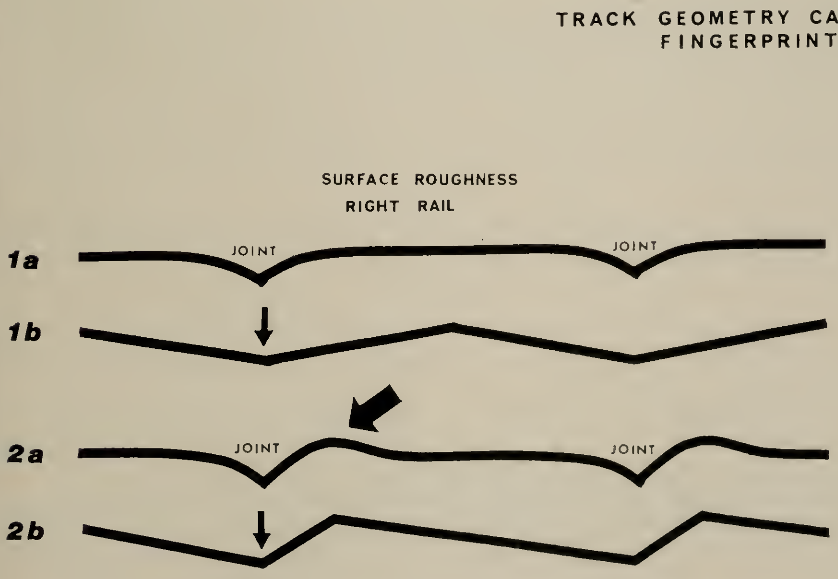


Fig. 11

defining its actual shape, and we ended up with the line 1B where we have summarized the level of detail to defining, on the average, only two points per rail length. One cannot help but wonder if any use could have been made from all the data we have ignored.

Let us now consider the surface roughness signal represented by line 2A. Again we have reduced this signal on the car to a series of high and low points, as in line 2B. You will readily notice, however, that the two signals 1A and 2A are not the same shape, because of the "bump" on 2A at the large arrow. This fact will be considered indirectly by the electronics, in that, because of this "bump," the drop in the joint on 2B will be calculated as being greater than the joint on 1B.

I would like to pose the following question, however: Does the actual shape of the signal have any meaning? I think the answer is "yes." Studies carried out by Canadian National indicate that a "bump" of the type shown in the signal 2A is the result of a bent rail end. We consider that it will be possible to isolate many such actual track or rail defects by studying the resultant signal. The concept is that each defect will have a fingerprint, so to speak, on the resultant electronic signals. We propose to carry out extensive tests, on several stretches of track with known defects. The result should be the development of a corresponding "fingerprint" for most types of defects. Once complete, we can re-program the Track Geometry Car to show not only what condition the track is in, but what is actually wrong with it.

CONCLUSION

I would like to close by saying that I believe the potential for Track Geometry Cars is virtually limitless for engineering management. Although I have not done the calculations, I believe you would find the rate of return unbelievably high for the investment in the car. If you will excuse my rather blatant optimism, I further believe Track Geometry Cars, and similar management tools, will prove, in the future, to be as revolutionary to maintenance of way management as the business computer has been to accounting management.

The Use of Track Analyzer Car Data in Inspection of Track and Maintenance Planning

76–653–12

By **ARVIE L. MAYNARD**
Engineer Maintenance of Way
Chessie System

The Chessie System's RI-2 (Roadway Inspection) car is designed for both good visual inspection of roadway and recording of track geometry. There is room for seating 20 people in theater-type tiered seats from which observers can get an unobstructed view of the roadway and track through full width and height windows at the rear of the car. Also, seven people can sit at floor level for easy conference, three of these in chairs facing the picture windows and four in a row of seats immediately behind.

Spring and Fall inspection trips are conducted over all of Chessie System's service routes. Special inspection trips are made at other times on selected branch lines.

Barring unexpected conflicts, the assistant chief engineer—maintenance makes the entire system inspections. The regional assistant chief engineer, division engineer and track supervisor sit with him at the observation end of the car to discuss maintenance matters during the inspection trips over their respective territories. These inspection trips provide a means for the senior engineering maintenance officer to give undivided attention to the problems of the individual track supervisor. Specific maintenance goals for the track supervisor are oftentimes assigned during these trips.

In addition to track, other system engineering disciplines make good use of the semi-annual inspection trips. The trips are particularly useful for signal and communications officers and the engineer of vegetation control for the visual inspections necessary for good maintenance planning. Because of the large observation seating capacity, it is possible for system and regional officers of these other disciplines to confer with their local supervision while inspecting the territories. Also, Transportation Department officers are on board. The RI-2 car is a vehicle for field coordination of the interlocking maintenance effort.

Three recordings of track data are drawn or printed during the inspection trip in addition to storing all of the information on magnetic tape:

1. An analog tracing of track geometry.
2. A printout of priority defects.
3. A summary of measured data.

Real-time viewing of the analog tracing on closed-circuit television is possible by all persons in the observation seats.

Now we call the report of critical track geometry defects the "track grading report." Perhaps "supervision grading report" would be more appropriate. If supervision is effective, the length of the track grading report should reduce from trip to trip.

Note: Discussion open until October 15, 1975.

The printout format is a simple listing of when, where and what, with room to show how corrective action is taken. When the inspection was made is shown on the header, together with an identification of the division and subdivision. Where the condition locates is identified for each entry by track number and distance from a mile post. The what is a simple definition of the condition as low joint, line, warp or gage. Asterisks beside gage entries indicate excess over standard gage, one asterisk for ¾-inch-wide gage, two asterisks for 1 inch wide and three asterisks for 1¼ inches wide. Four asterisks indicate gage more than 1½ inches wide. The magnitude of the other entries depends upon the maximum authorized speed for the territory being inspected. The computer is programmed to printout conditions more restrictive than the FRA Track Safety Standards. The original priority defect printout is given to the track supervisor. Copies are given to the division engineer and regional assistant chief engineer. It is the responsibility of the track supervisor to investigate each item and to take prompt action on critical defects. He is to either schedule work by basic track forces on the sub-critical items or recommend other action to the division engineer.

Traces are made of line, cross level, surface and gage on the cross-hatched analog chart. For ease in reading the chart on the closed circuit television and for analysis later, there are heavier longitudinal lines for 10 degrees of alignment, 5 inches of cross level, and 1 inch wide gage. One can easily determine where superelevation and curvature do not match. Also poor general line and cross level are readily apparent. The analog tracing is given to the division engineer when he leaves the car. It is his responsibility to have an analysis made of the chart to determine where major maintenance is required. Most of the division engineers will edit the chart with colored pencil marking locations needing attention. This visual analysis of the analog chart is an aid to the division engineer in firming a program for production forces. The printout of priority defects together with the track supervisor's comments on them also help the division engineer develop a sound maintenance plan.

Other than the invaluable benefit of the visual track inspection and on-board conferences, the mile-by-mile summary printout is the basic RI-2 output used by the system office in supervising maintenance planning.

This printout indicates the number of low joints in each mile in four increments of magnitude: ¼ to ½ inch, ½ to ¾ inch, ¾ to 1 inch and those over 1 inch low.

The gage of the entire mile is printed out with incremental deviations as a percentage of the total mile. In reading the printout, one must visualize a period preceding the last digit. Under the column headed 0–½ an entry of 1,000 would indicate 100% of the gage was within ½ inch of standard. Other columns indicate the percentage of gage ½ to ¾ inch wide, ¾ to 1 inch wide and all over 1 inch wide.

Line condition is separated by percentage into two categories: small and large. The dividing point is a 1½ degree change in 20 ft. Program maintenance proposals from the divisions are plotted on the summary printout to check if a good plan is being formulated.

The computer on board the car has been programmed to analyze the mile-by-mile data for individual territories and produce a track index report. A separate index is shown for low joints, low joints combined with line and one covering gage. The computer is also programmed to make separate sorts of this data in descending order of miles and indices. Projected is the sort of low joints. Although we are considering assigning an overall track quality index to each mile by combining all parameters, we have not resolved the mechanics in arriving at our goal.

The kinds of maintenance activity which would be influenced by the index reports are:

1. Spot surfacing
2. Out of face raising and lining
3. Gaging, or perhaps curve patching or cross tie renewal after field investigation of the reason for poor gage.

The low-joint index is the approximate summation of those joints' depths for all low joints that are ¼ inch or greater in depth in a mile. This index is meant to indicate where spot surfacing is required.

Out-of-face surfacing and lining are correlated because lining is most easily accomplished when the track is raised on fresh unconsolidated ballast. The low joint and line index is computed by adding the low joint index to twice a line index. The line index is the total inches of alignment error if the line were measured with a 62-ft cord once per rail length.

The gage index represents the total number of inches of wide gage per mile. Gage readings are taken every foot.

The index report was first produced during last fall's inspection trip. I feel it is most useful in preparing a draft maintenance plan. We are now educating the division engineers to the value of it.

The RI-2 information is used in conjunction with other input as an aid in planning the rail program. We have a separate computer program for new rail territory whereby an annual printout is produced, giving a priority for laying rail based on past history of tonnage carried in relation to the rail in track, grade and curvature. The rail surface data from RI-2 printouts is listed on the rail priority printout as an additional guide for establishing rail laying priorities. Our computer programmers are working on a system to print the RI-2 and rail defect information or the rail priority printout instead of it being plotted manually.

The RI-2 is designed to give useful output for maintenance planning by each level from track supervisor to chief engineer.

Planning and scheduling the work of basic track forces is done by the track supervisor. The priority printout provides input for the track supervisor to schedule corrective maintenance. The summary printout, together with the listing of sub-critical items on the priority printout are useful to the supervisor in his monthly scheduling of the work of basic forces.

The division engineer approves the basic force plan and originates the production force proposal. He has the summary printout and the various index report sorts together with the analog tracing as aids.

The regional assistance chief engineer approves the division engineers' production force proposals and originates a regional rail laying priority. He has the observation end conferences with the assistant chief engineer—maintenance and the summary printouts as aids.

The system office finalizes the rail program and authorizes all programs within budget limitations. RI-2 output of visual roadway and track inspection, together with printouts, are useful in establishing system priorities.

Engineering Systems Approach to Study for United States Railway Association

76–653–13

INTRODUCTION

By HARRY R. DAVIS
Director of Facilities Evaluation and Planning
United States Railway Association

Having been a non-participating member of AREA for many years, I am most happy to be here and participate, in a small way, by introducing the next two speakers who will present the United States Railway Association's inventory and assessment project.

For those of you who may not be aware of what USRA is and what its goals are, I will take a minute to explain both briefly.

The Association was established under the Regional Rail Reorganization Act of 1973 to plan a rail system in the northeast and midwest states. The railroads that are covered by the provisions of the Act and are part of the Preliminary Plan and the continuing planning are the Penn Central Transportation Company, the Reading Company, the Lehigh Valley, the Central of New Jersey, Lehigh and Hudson River, the Ann Arbor, the Erie Lackawanna, and their affiliates.

The rail transportation system that evolved, presently known as the Preliminary System Plan and, later this year, will be known as the Final System Plan, has eight specific goals to meet. They are: (1) viability, (2) adequate transportation needs and service requirements of the region, (3) establishment of improved high-speed rail passenger service, (4) preservation of service patterns and energy resources, (5) retention and promotion of competition, (6) attainment and maintenance of environmental standards, (7) efficient and safe operation for both freight and passenger, and (8) minimization of job losses. The two most difficult goals to plan for, as you can imagine, were viability and preservation of competition.

The presentation today cuts across most, if not all, of the goals. In order to evaluate the many options that were considered, it was necessary to provide pro forma financial projections for each. The office I direct was responsible for the expenses of both the maintenance of equipment and maintenance of way functions.

Prior to the required staffing of USRA, those responsible at the Federal Railroad Administration recognized the need for an inventory and assessment of the facilities of the bankrupt railroads to be included in the planning.

Many studies were available which had been conducted on behalf of individuals and organizations with divergent social, political and economic interest. Without questioning the validity of those studies, none provided a comprehensive and compatible inventory and assessment of the facilities of the railroads included in the planning.

The Federal Railroad Administration initiated the project and the Association managed and developed the maintenance of way planning from the results.

Some of the major findings of the project were the following deferred units of work that were required to restore the facilities to their previous best level of

---

Note: Discussion open until October 15, 1975.

utility: Of the 43,000 miles of track assessed, there were 10,522 track miles of rail requiring replacement; 29.1 million failed ties; 536,696 failed switch timbers; 10,093 turnouts to replace; and 642,000 track feet of road crossing requiring replacement. We don't pretend the inventory was that exact but the sampling expanded to provide these figures.

Combined with the requirements of the other 13 major facilities, the rehabilitation of the fixed plants of the railroads in the plan was estimated to be $3.8 billion. This estimate was for "instant" rehabilitation in third-quarter 1974 dollars, and included all the facilities studied.

By comparison, for the Preliminary System Plan's 28,000 track miles, the requirements were 20.6 million ties (a reduction of 8.5 million) and 8,340 track miles of rail (a reduction of 2,282 miles). The replacement of this and other material was constrained by the availability of material, equipment, and labor. Also considered in programming was the train interference. The constraints were applied and the rehabilitation requirements were programmed over the appropriate time required to accomplish the work.

The supporting requirements such as tie cars, ballast cars, and welded rail hauling trains were developed from the programs. As most of you are aware, the most critical material constraint is the availability of rail.

The rehabilitation cost developed by USRA for the Preliminary System Plan was $2 billion over a 14-year program. This cost is uninflated and in third-quarter 1974 dollars. This figure does not appear in the plan and is for comparison. The rehabilitation figures in the plan have had modified betterment accounting applied, and are in 1973 dollars. Under this method, the rehabilitation is $2.3 billion.

Modified betterment accounting simply stated provides for capitalizing and depreciating the cost of work performed in excess of the normal. Since the plan starts with a debilitated plant, this method provides for capitalizing the rebuilding.

The continuing planning process for my staff to provide the required information for the Final System Plan will include:

(1) Monitoring the effect of the 1975 maintenance of way and maintenance of equipment programs on the conditions of the facilities and equipment that become part of the Plan.

(2) Refining the data collected for the project, that is today's subject, in order to quickly apply it to changing options.

(3) Location scheduling of improvements to provide the most in operating efficiencies.

(4) Refining the timing of the mix of rehabilitation, normal maintenance and interim or expedient maintenance.

I mention these few because the project information will play a large role in the process. Before moving on with the program, I want you to know the staff at the United States Railway Association believes that the opportunity to reorganize the system is not only unique, but that it is also probably the last chance anybody will have to attempt it. If ConRail does not work, the logical and inescapable next step is nationalization. I am sure that we all agree that we don't want that.

The organization and field work of the project will be presented by H. L. (Ledge) Chamberlain, project engineer with Sverdrup & Parcel and Associates, Inc.

ORGANIZATION AND FIELD WORK

By **H. L. CHAMBERLAIN**
Project Engineer
Sverdrup & Parcel and Associates

Before proceeding further with this presentation, your committee would emphasize that this is in no way a commentary on the pros and cons of the Reorganization Act, nor is it a critique of the specifications and the prescribed procedures by means of which the work was carried out. Instead, this will be a description of how the disciplines of systems engineering were applied in the solution of a huge problem of enormous complexity.

Because of the time limit set for this presentation, we will limit our discussion to the organization, field work and data accumulation as carried out by Sverdrup & Parcel on their assigned territory, and then to the rehabilitation planning and cost estimating as done by the DeLeuw, Cather Organization for their assigned territory. The work of these two companies may be considered as typical of the entire effort since each of the organizations involved in the work, although acting independently, were rigidly bound by the specifications and procedures set down by the Technical Direction Contractor.

It is difficult to describe the scope and extent of this project, bearing in mind that there were approximately 21,000 route miles and over 30,000 track miles involved, together with all the associated facilities of an operating railroad. Acting as the engineering staff for USRA, the Technical Direction Contractor faced a severe challenge in organizing the project and providing the specifications and procedures for the six Associate Contractors who had been selected to carry out the work. These Associate Contractors are listed on Table I, together with a breakdown of their assigned territories by geographical area and by mileage. Obviously, it was necessary to coordinate the effort, monitor the work and see that a uniform and consistent flow of information was obtained under uniform procedures.

The charge from USRA was to conduct an inventory of the railroad's physical plant, evaluate the condition of the plant, assess the validity of the railroad's records, design a rehabilitation program and provide a cost estimate for rehabilitating the plant to a previously existing level of utility without upgrading beyond that. To carry out the inventory in minute detail, tie by tie and rail by rail, would have been impossible under the budget with which USRA had to work and, in particular, under the severe time constraint set by the Reorganization Act. Under the terms of the Act, the USRA had only 120 days from the time the Associate Contractors were given notice to proceed in which to report back to the Congress. This meant that the Associate Contractors had to carry out their field and assessment work in about 60 days and submit their final plans and estimates in about 100 days so that the Technical Direction Contractor would have sufficient lead time to assemble its final report to USRA. Under the constraints imposed, it was mandatory to invoke the disciplines of systems engineering and the techniques of statistical analysis so that a statistical model of a railroad's existence and condition could be created. Within the sampling parameters set by the Technical Direction Contractor, a statistical model was created from which a valid overall estimate of conditions and costs could be derived. Fig. 1 provides a picture of the interflow of information as obtained by the Associate Contractors, processed and checked, and then for-

TABLE 1

MILEAGE BY ASSOCIATE CONTRACTOR

	MAIN	BRANCH	YARD	ROUTE MILES
BECHTEL				
Penn Central Eastern	1940	1686	2288	2410
Penn Central Metro	711	137	215	388
Pennsylvania Reading Seashore Line	166	233	27	307
TOTAL	2817	2056	2530	3105
DDL & N				
Penn Central Central	2967	2573	2144	3910
TOTAL	2967	2573	2144	3910
M & K				
Penn Central Southern	2995	2730	2134	4652
TOTAL	2995	2730	2134	4652
S & P				
Penn Central Northern (-)	634	1187	826	1562
Penn Central Western (-)	1843	830	1133	1754
Ann Arbor	362	7	43	299
TOTAL	2839	2024	2002	3615
DEL. C. & CO.				
Penn Central North Eastern	2074	1885	2090	2967
Cleveland Division	492	164	384	245
Canada Division	470	37	99	273
TOTAL	3036	2086	2573	3485
S.T.V.				
Reading	1631	453	551	1162
Central New Jersey	347	222	250	328
Lehigh Valley	859	670	569	988
Lehigh & Hudson River	94		7	76
TOTAL	2931	1345	1377	2554
GRAND TOTAL	17585	12814	12760	21321

SOURCE: ICC ANNUAL REPORTS R - 1 AND PCTC REGIONAL SUMMARY OF MILEAGE.

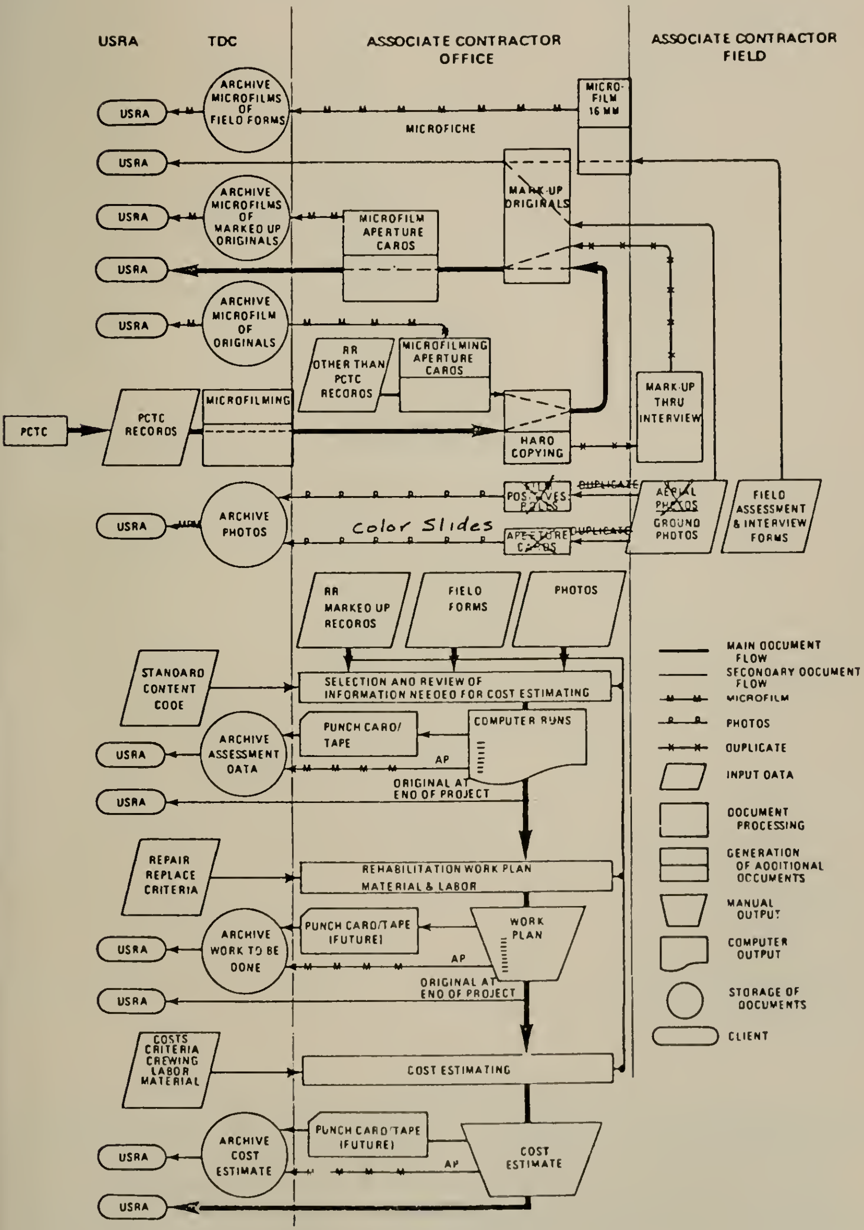
warded to the Technical Direction Contractor for monitor review and then subsequently passed on to USRA for their downstream evaluation studies. Although Fig. 1 shows aerial photography and microfilming of all documents, the budget and time constraints precluded these features. There was no aerial photography carried out and all submissions to USRA were in hard copy form.

Sverdrup & Parcel were assigned the Ann Arbor Railroad, the Penn Central's Western Region (less the Cleveland Division) and the Penn Central's Northern Region (less the Canada Division). Keying their efforts to the railroad's own organization, S&P divided their forces on a railroad division basis with field offices at division headquarters, this being where the key railroad personnel were located and where the detailed records were maintained. Each division group was in charge of an experienced and competent railroad maintenance engineer, supported by engineering specialists and technicians as required. The division groups were manned by personnel from the main office as well as from regional offices at Seattle, Boston, and New York. Staff consultants were also employed, both in the field and at the home office to assist in evaluation and estimating.

Under the division group leader were the track inspection teams, usually of two or three persons depending upon the territory involved. There was also assigned to each division a qualified bridge inspector and a qualified communications and signal inspector, both of whom worked closely with railroad personnel in carrying out their assignments. In addition to the assigned division teams there were two roving mechanical-electrical inspection teams to cover the shop, terminal, electrical and servicing facilities on the assigned territory. Finally, each division field office had a division office manager to handle correspondence, the minutia of day-to-day scheduling, the processing of photography and the screening and evaluation of field inspection reports before the daily submittal to home office. The division group leader, in addition to being responsible for overall performance, worked with the inspection teams, at the field office or with railroad personnel as the situation dictated.

Obviously it was necessary to assign priorities and to categorize the various facility groups which had to be inventoried and assessed. The assigned line priorities were those set forth in the report of the Secretary of Transportation, dated February 1, 1974. The field work was tightly scheduled in accordance with line priority, with occasional overlapping so that the inspection teams would not have to backtrack. The facility categories which were established are shown here on Table 2. Obviously there was some slight overlapping and there may have been facility types which were not taken into consideration, but those shown represent the basic elements of a railroad. Each facility group, depending upon its importance or magnitude was assigned a sampling frequency.

Scheduling was of crucial importance in carrying out the field work for several reasons. First was the overall deadline which had to be met. Second, it was imperative that the rehabilitation planning and cost estimating follow behind the field reporting as closely as possible. Also, it was necessary to complete the field work in sufficient time to allow for the home office to complete the study and estimating work within the deadline. It was not unusual for the field teams to work 12 or 14 hours per day and often there were 7-day work weeks. S&P received notice to proceed on August 1, 1974. Using the first week for setting up field offices and organizing the teams, the field work was started. It was completed during the first week



FLOW OF INFORMATION

Fig. 1

TABLE 2

Code	*Facility*
TR	Trackwork
YA	Yards
SH	Shops
SF	Servicing Facilities
BR	Bridges
TU	Tunnels
BL	Buildings
FT	Freight Terminals
MT	Marine Terminals
SI	Signals
CO	Communications
DP	Data Management
EL	Traction Power
OE	Other Electrical

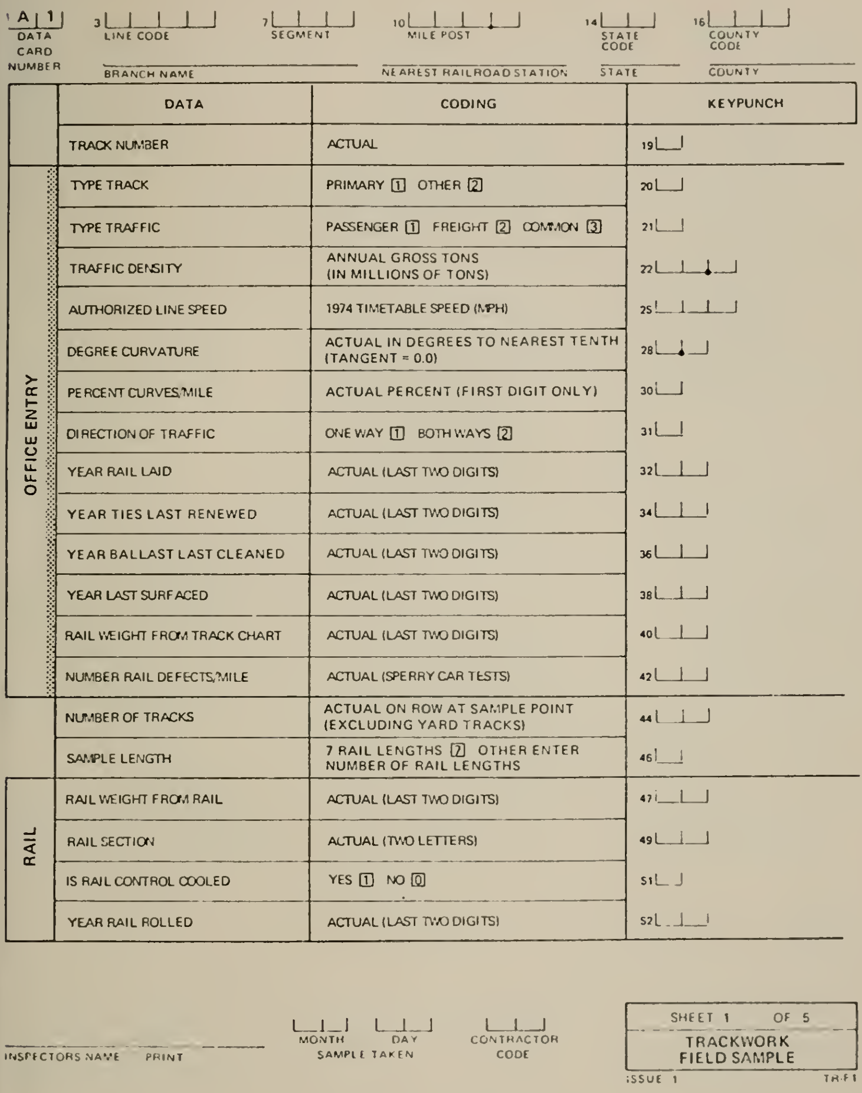
TABLE 3

TRACKWORK SAMPLES

Group	Quantity	Coverage (percent)	Number of Samples	Sampling Frequency
Tangent track	22,000 miles	2.5	11,000	1/20 mile per 2 miles
Curved track	8,000 miles	2.5	4,000	1/20 mile per 2 miles
RR crossings	900	20	180	Every fifth one
Grade crossings	36,000	5	1,800	Every 20th one
Turnouts within Interlocking limits	12,000	10	1,200	Every third turnout in every third interlocking
Turnouts outside of interlocking limits	12,000	10	1,200	Every tenth one

in October, well within schedule. During this time some 18,000 35-mm photographs were taken and upwards of 30,000 field inspection forms and verified railroad records were submitted.

Time does not permit discussion of all of the facility groups and we will, therefore, limit ourselves to track inspection and evaluation. Table 3 illustrates the quantity, coverage and sampling frequency. To comment on the validity of the sampling procedure is beyond the scope of this report, but it is believed that the



1 A 1 DATA CARD NUMBER

3 LINE CODE

7 SEGMENT

10 MILE POST

14 STATE CODE

16 COUNTY CODE

BRANCH NAME

NEAREST RAILROAD STATION

STATE

COUNTY

	DATA	CODING	KEYPUNCH
	TRACK NUMBER	ACTUAL	19
OFFICE ENTRY	TYPE TRACK	PRIMARY $\boxed{1}$ OTHER $\boxed{2}$	20
	TYPE TRAFFIC	PASSENGER $\boxed{1}$ FREIGHT $\boxed{2}$ COMMON $\boxed{3}$	21
	TRAFFIC DENSITY	ANNUAL GROSS TONS (IN MILLIONS OF TONS)	22
	AUTHORIZED LINE SPEED	1974 TIMETABLE SPEED (MPH)	25
	DEGREE CURVATURE	ACTUAL IN DEGREES TO NEAREST TENTH (TANGENT = 0.0)	28
	PERCENT CURVES/MILE	ACTUAL PERCENT (FIRST DIGIT ONLY)	30
	DIRECTION OF TRAFFIC	ONE WAY $\boxed{1}$ BOTH WAYS $\boxed{2}$	31
	YEAR RAIL LAID	ACTUAL (LAST TWO DIGITS)	32
	YEAR TIES LAST RENEWED	ACTUAL (LAST TWO DIGITS)	34
	YEAR BALLAST LAST CLEANED	ACTUAL (LAST TWO DIGITS)	36
	YEAR LAST SURFACED	ACTUAL (LAST TWO DIGITS)	38
	RAIL WEIGHT FROM TRACK CHART	ACTUAL (LAST TWO DIGITS)	40
	NUMBER RAIL DEFECTS/MILE	ACTUAL (SPERRY CAR TESTS)	42
	NUMBER OF TRACKS	ACTUAL ON ROW AT SAMPLE POINT (EXCLUDING YARD TRACKS)	44
	SAMPLE LENGTH	7 RAIL LENGTHS $\boxed{7}$ OTHER ENTER NUMBER OF RAIL LENGTHS	46
RAIL	RAIL WEIGHT FROM RAIL	ACTUAL (LAST TWO DIGITS)	47
	RAIL SECTION	ACTUAL (TWO LETTERS)	49
	IS RAIL CONTROL COOLED	YES $\boxed{1}$ NO $\boxed{0}$	51
	YEAR RAIL ROLLED	ACTUAL (LAST TWO DIGITS)	52

INSPECTORS NAME PRINT

MONTH DAY SAMPLE TAKEN

CONTRACTOR CODE

SHEET 1 OF 5

TRACKWORK FIELD SAMPLE

ISSUE 1

TR-F1

Fig. 2

inspection provided a valid data base from which conclusions could be drawn which were accurate within acceptable limits.

Fig. 2 illustrates the type of information which was gathered by the inspection teams at each trackwork sampling point. Not only were actual physical measurements

A 1 DATA CARD NUMBER	LINE CODE	SEGMENT	MILE POST	STATE CODE	COUNTY CODE

	DATA	CODING	KEYPUNCH
RAIL (CONT.)	AVERAGE LENGTH OF RAIL IN TRACK	39 [9] 36 [6] 33 [3] OTHER [0] SPECIFY ____	54
	POSSIBLE RAIL DISPOSITION	RAIL COULD BE RELAID AS IS [A] RAIL COULD BE CROPPED AND RELAID [C] RAIL SHOULD BE SCRAPPED [Z]	55
	PERCENT REQUIRING REPLACEMENT	ACTUAL PERCENT (FIRST DIGIT ONLY)	56
	GRINDING REQUIRED	YES [1] NO [0]	57
	PERCENT REQUIRING WELD/GRIND	ACTUAL PERCENT (FIRST DIGIT ONLY)	58
	PRIMARY REASON FOR REPLACEMENT	WEAR [1] SERVICE FAILURE [2] SHELL [3] BOLTHOLE BREAKS [4] END BENT [5] OTHER [6]	59
RAIL WEAR	RAIL HEAD WIDTH (W/VERNIER)	(IF TRANSPOSED RAIL ENTER 0.00)	
	HIGH RAIL (AT GAGELINE)	ACTUAL MEASUREMENT TO NEAREST HUNDREDTH	
	LOW RAIL (AT GAGELINE)	ACTUAL MEASUREMENT TO NEAREST HUNDREDTH	
	HEAD WIDTH NEW	TO NEAREST HUNDREDTH	
	WEAR HIGH RAIL	TO NEAREST SIXTEENTH	60 SIXTEENTHS
	WEAR LOW RAIL	TO NEAREST SIXTEENTH	62 SIXTEENTHS
	RAIL HEIGHT HIGH RAIL	ACTUAL MEASUREMENT TO NEAREST TENTH	
	LOW RAIL	ACTUAL MEASUREMENT TO NEAREST TENTH	
	RAIL HEIGHT NEW	TO NEAREST TENTH	
	WEAR HIGH RAIL	TO NEAREST SIXTEENTH	64 SIXTEENTHS
	WEAR LOW RAIL	TO NEAREST SIXTEENTH	66 SIXTEENTHS
	GENERAL FIELD NOTES AND COMMENTS	YES [1] NO [0]	68 END CARD 1
NOTES			

INSPECTORS NAME PRINT

MONTH DAY SAMPLE TAKEN

CONTRACTOR CODE

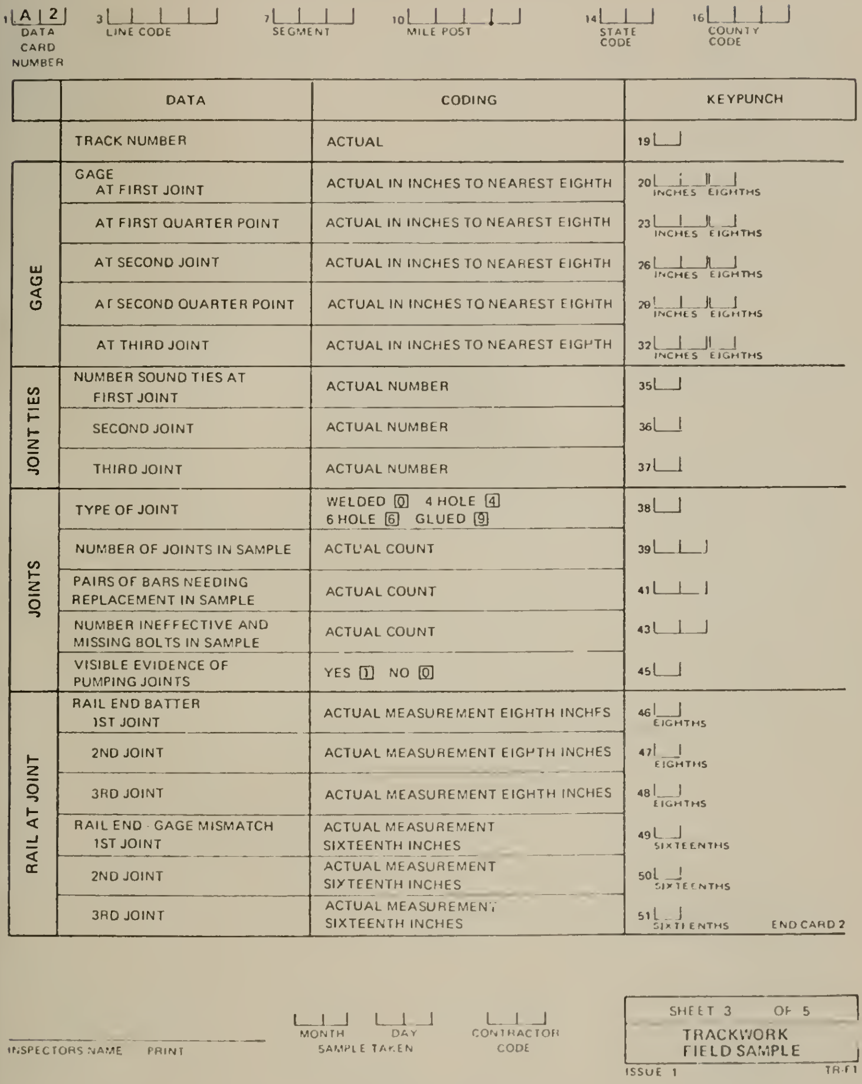
SHEET 2 OF 5

TRACKWORK FIELD SAMPLE

ISSUE 1 TR-F1

Fig. 2 (cont'd)

taken but a regulated series of photographs made to assist in making the final evaluation and also to verify to the Technical Direction Contractor and to USRA the conditions encountered. The other facility groups were sampled, inventoried and assessed in a similar manner as shown by Fig. 3, the first form sheet for bridge



1 A 2 DATA CARD NUMBER
3 LINE CODE
7 SEGMENT
10 MILE POST
14 STATE CODE
16 COUNTY CODE

	DATA	CODING	KEYPUNCH
	TRACK NUMBER	ACTUAL	19
GAGE	GAGE AT FIRST JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	20 INCHES EIGHTHS
	AT FIRST QUARTER POINT	ACTUAL IN INCHES TO NEAREST EIGHTH	23 INCHES EIGHTHS
	AT SECOND JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	26 INCHES EIGHTHS
	AT SECOND QUARTER POINT	ACTUAL IN INCHES TO NEAREST EIGHTH	29 INCHES EIGHTHS
	AT THIRD JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	32 INCHES EIGHTHS
JOINT TIES	NUMBER SOUND TIES AT FIRST JOINT	ACTUAL NUMBER	35
	SECOND JOINT	ACTUAL NUMBER	36
	THIRD JOINT	ACTUAL NUMBER	37
JOINTS	TYPE OF JOINT	WELDED 0 4 HOLE 4 6 HOLE 6 GLUED 9	38
	NUMBER OF JOINTS IN SAMPLE	ACTUAL COUNT	39
	PAIRS OF BARS NEEDING REPLACEMENT IN SAMPLE	ACTUAL COUNT	41
	NUMBER INEFFECTIVE AND MISSING BOLTS IN SAMPLE	ACTUAL COUNT	43
	VISIBLE EVIDENCE OF PUMPING JOINTS	YES 1 NO 0	45
RAIL AT JOINT	RAIL END BATTER 1ST JOINT	ACTUAL MEASUREMENT EIGHTH INCHES	46 EIGHTHS
	2ND JOINT	ACTUAL MEASUREMENT EIGHTH INCHES	47 EIGHTHS
	3RD JOINT	ACTUAL MEASUREMENT EIGHTH INCHES	48 EIGHTHS
	RAIL END - GAGE MISMATCH 1ST JOINT	ACTUAL MEASUREMENT SIXTEENTH INCHES	49 SIXTEENTHS
	2ND JOINT	ACTUAL MEASUREMENT SIXTEENTH INCHES	50 SIXTEENTHS
	3RD JOINT	ACTUAL MEASUREMENT SIXTEENTH INCHES	51 SIXTEENTHS END CARD 2

INSPECTORS NAME PRINT
MONTH DAY SAMPLE TAKEN
CONTRACTOR CODE

SHEET 3 OF 5
TRACKWORK
FIELD SAMPLE
ISSUE 1 TR-F1

Fig. 2 (cont'd)

inspection. Going back to the first sheet of the track inspection sample report, it should be noted that most of the information was to be entered from railroad records. This was the primary method of assessing the validity of existing data. The actual field observations could be screened against what information was at hand.

1 [illegible] 3 DATA CARD NUMBER
3 LINE CODE
7 SEGMENT
10 MILE POST
14 STATE CODE
16 COUNTY CODE

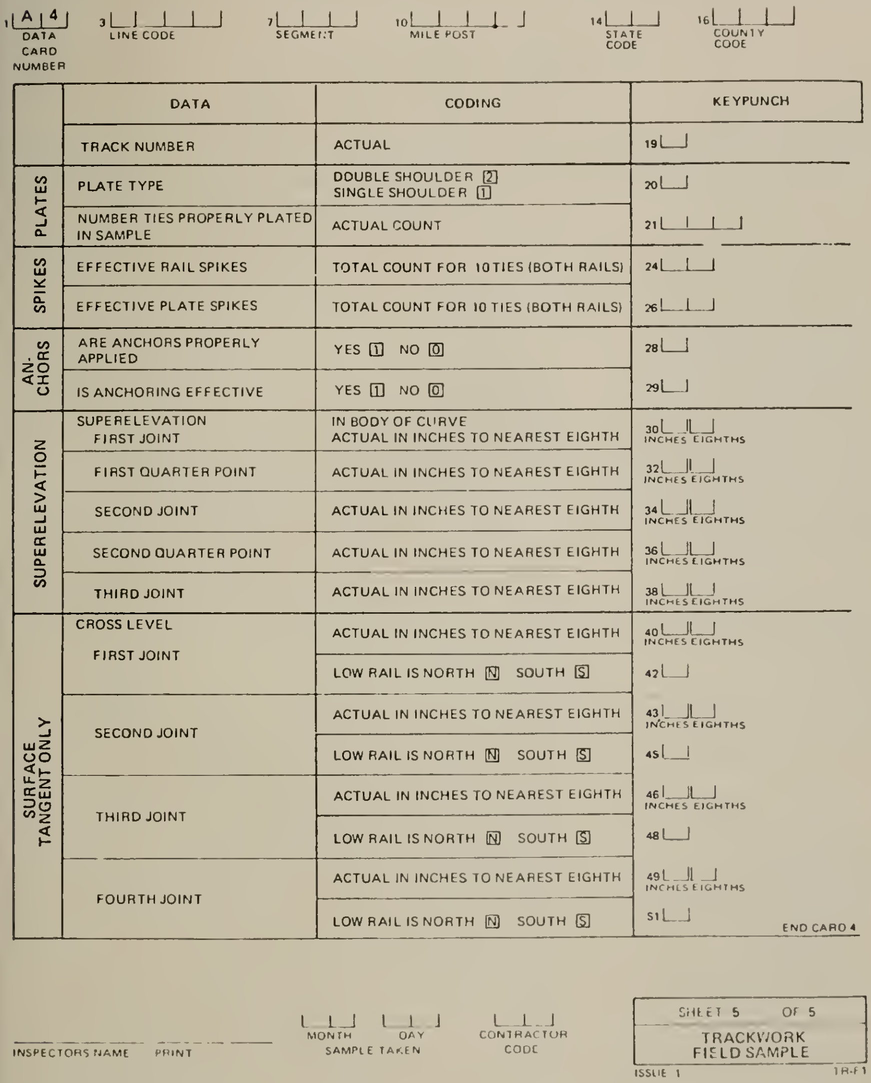
	DATA	CODING	KEYPUNCH
	TRACK NUMBER	ACTUAL	19
RAIL AT JOINT (CONT.)	ALIGNMENT	SATISFACTORY [A] UNSATISFACTORY [Z]	20
	SURFACE	SATISFACTORY [A] SPOT SURFACING REQUIRED [C] OUT OF FACE SURFACING REQUIRED [Z]	21
	BALLAST	STONE [1] SLAG [2] CINDER [3] OTHER [4]	22
	BALLAST WORK NEEDED	NONE [A] RAISE [C] CLEAN SHOULDER [T] CLEAN CRIB & SHOULDER [X] SLED [Z]	23
ROW	CUT CONDITION - SLOPES	STABLE [A] NEED REPAIR [X] DANGEROUS [Z] (SPECIFY LENGTH IN NOTES)	24
	FILL CONDITION - SLOPES	STABLE [A] NEED REPAIR [X] DANGEROUS [Z] (SPECIFY LENGTH IN NOTES)	25
	DITCHES	GOOD [A] FAIR [C] POOR [X] NEEDED [Z] (SPECIFY LENGTH IN FIELD NOTES)	26
	CULVERTS	GOOD [A] FAIR [C] POOR [X] NEEDED [Z]	27
VEGETATION	WITH IN BALLAST	NONE [A] LIGHT [C] HEAVY [Z]	28
	ON SHOULDER	NONE [A] LIGHT [C] HEAVY [Z]	29
	OUTSIDE SHOULDER	NONE [A] LIGHT [C] HEAVY [Z]	30
TIES	TOTAL NUMBER TIES IN SAMPLE	ACTUAL COUNT	31
	TOTAL BAD TIES IN SAMPLE	ACTUAL COUNT	34
	NUMBER SKEWED TIES IN SAMPLE	ACTUAL COUNT	37
	MAX. CENTER DIST. SOUND TIES IN FIRST RAIL LENGTH	ACTUAL MEASUREMENT IN NEAREST WHOLE INCH	39
	IN SECOND RAIL LENGTH	ACTUAL MEASUREMENT IN NEAREST WHOLE INCH	42
	AVERAGE TIE LENGTH	ACTUAL MEASUREMENT (NEAREST FOOT)	45
	AVERAGE TIE WIDTH	ACTUAL (NEAREST WHOLE INCH)	47
	NUMBER OF PHOTOGRAPHS TAKEN		48
	GENERAL NOTES AND FIELD COMMENTS	YES [1] NO [0]	49 END CARD 3

INSPECTORS NAME PRINT
MONTH DAY SAMPLE TAKEN
CONTRACTOR CODE

SHEET 4 OF 5
TRACKWORK FIELD SAMPLE
ISSUE 1
TR-F1

Fig. 2 (cont'd)

Each day the field teams made their observations and submitted data to the field office. There the photographs were developed and checked and inspection reports were reviewed before submission to the home office. There, the photographs were catalogued and the data from the field inspection reports keypunched and



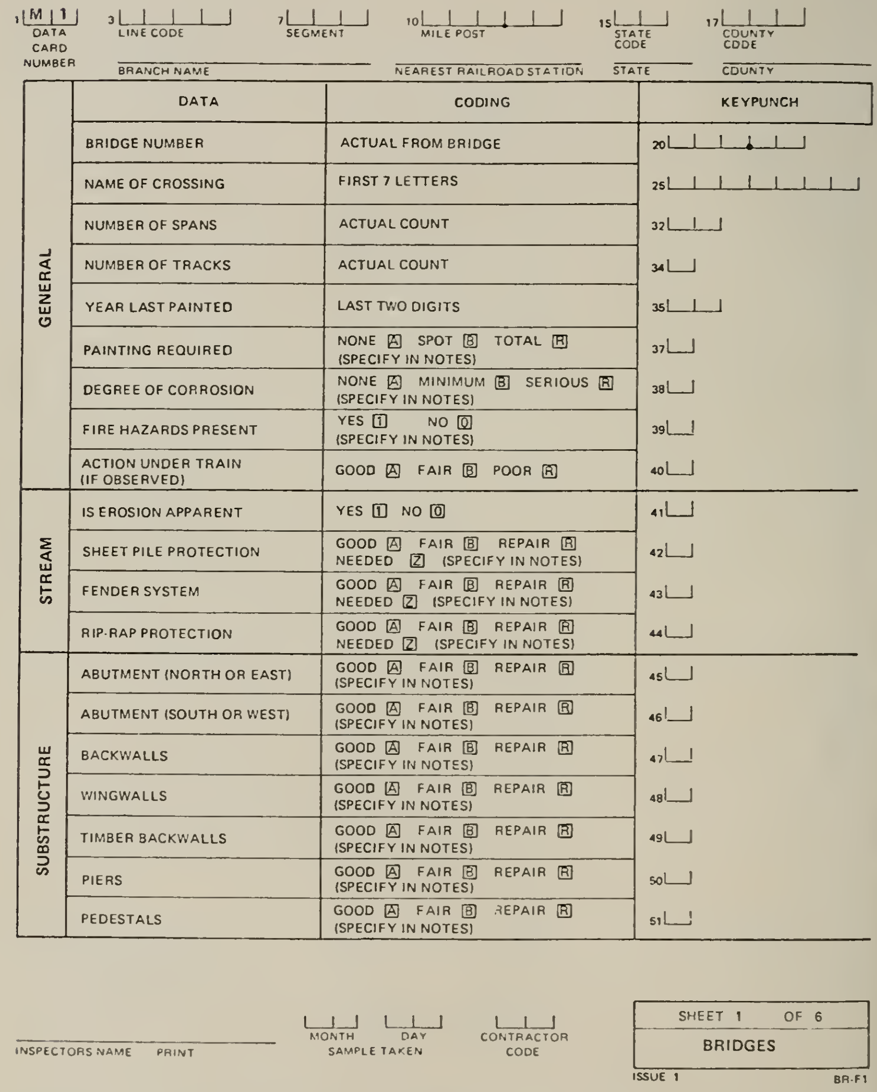
1 A 4 DATA CARD NUMBER
3 LINE CODE
7 SEGMENT
10 MILE POST
14 STATE CODE
16 COUNTY CODE

	DATA	CODING	KEYPUNCH
	TRACK NUMBER	ACTUAL	19
PLATES	PLATE TYPE	DOUBLE SHOULDER [2] SINGLE SHOULDER [1]	20
	NUMBER TIES PROPERLY PLATED IN SAMPLE	ACTUAL COUNT	21
SPIKES	EFFECTIVE RAIL SPIKES	TOTAL COUNT FOR 10 TIES (BOTH RAILS)	24
	EFFECTIVE PLATE SPIKES	TOTAL COUNT FOR 10 TIES (BOTH RAILS)	26
AN-CHORS	ARE ANCHORS PROPERLY APPLIED	YES [1] NO [0]	28
	IS ANCHORING EFFECTIVE	YES [1] NO [0]	29
SUPERELEVATION	SUPERELEVATION FIRST JOINT	IN BODY OF CURVE ACTUAL IN INCHES TO NEAREST EIGHTH	30 INCHES EIGHTHS
	FIRST QUARTER POINT	ACTUAL IN INCHES TO NEAREST EIGHTH	32 INCHES EIGHTHS
	SECOND JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	34 INCHES EIGHTHS
	SECOND QUARTER POINT	ACTUAL IN INCHES TO NEAREST EIGHTH	36 INCHES EIGHTHS
	THIRD JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	38 INCHES EIGHTHS
SURFACE TANGENT ONLY	CROSS LEVEL FIRST JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	40 INCHES EIGHTHS
		LOW RAIL IS NORTH [N] SOUTH [S]	42
	SECOND JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	43 INCHES EIGHTHS
		LOW RAIL IS NORTH [N] SOUTH [S]	45
	THIRD JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	46 INCHES EIGHTHS
		LOW RAIL IS NORTH [N] SOUTH [S]	48
	FOURTH JOINT	ACTUAL IN INCHES TO NEAREST EIGHTH	49 INCHES EIGHTHS
		LOW RAIL IS NORTH [N] SOUTH [S]	51 END CARD 4

INSPECTORS NAME PRINT
MONTH DAY SAMPLE TAKEN
CONTRACTOR CODE
SHEET 5 OF 5
TRACKWORK FIELD SAMPLE
ISSUE 1 TR-F1

Fig. 2 (cont'd)

entered into a previously designed computer system for editing, sorting and error checking before being compiled into final form from which further evaluation could be made. From this final summary the rehabilitation programs and cost estimates could now be derived. To describe how this was done, I will turn the podium over to R. P. Howell, chief railroad engineer of the DeLeuw, Cather Organization.



1 M 1 DATA CARD NUMBER
3 ☐☐☐☐ LINE CODE
7 ☐☐☐ SEGMENT
10 ☐☐☐☐☐ MILE POST
15 ☐☐ STATE CODE
17 ☐☐☐ COUNTY CODE

BRANCH NAME ______
NEAREST RAILROAD STATION ______
STATE ______
COUNTY ______

	DATA	CODING	KEYPUNCH
GENERAL	BRIDGE NUMBER	ACTUAL FROM BRIDGE	20 ☐☐☐☐☐
	NAME OF CROSSING	FIRST 7 LETTERS	25 ☐☐☐☐☐☐☐
	NUMBER OF SPANS	ACTUAL COUNT	32 ☐☐
	NUMBER OF TRACKS	ACTUAL COUNT	34 ☐
	YEAR LAST PAINTED	LAST TWO DIGITS	35 ☐☐
	PAINTING REQUIRED	NONE A SPOT B TOTAL R (SPECIFY IN NOTES)	37 ☐
	DEGREE OF CORROSION	NONE A MINIMUM B SERIOUS R (SPECIFY IN NOTES)	38 ☐
	FIRE HAZARDS PRESENT	YES 1 NO 0 (SPECIFY IN NOTES)	39 ☐
	ACTION UNDER TRAIN (IF OBSERVED)	GOOD A FAIR B POOR R	40 ☐
STREAM	IS EROSION APPARENT	YES 1 NO 0	41 ☐
	SHEET PILE PROTECTION	GOOD A FAIR B REPAIR R NEEDED Z (SPECIFY IN NOTES)	42 ☐
	FENDER SYSTEM	GOOD A FAIR B REPAIR R NEEDED Z (SPECIFY IN NOTES)	43 ☐
	RIP-RAP PROTECTION	GOOD A FAIR B REPAIR R NEEDED Z (SPECIFY IN NOTES)	44 ☐
SUBSTRUCTURE	ABUTMENT (NORTH OR EAST)	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	45 ☐
	ABUTMENT (SOUTH OR WEST)	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	46 ☐
	BACKWALLS	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	47 ☐
	WINGWALLS	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	48 ☐
	TIMBER BACKWALLS	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	49 ☐
	PIERS	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	50 ☐
	PEDESTALS	GOOD A FAIR B REPAIR R (SPECIFY IN NOTES)	51 ☐

INSPECTORS NAME PRINT ______

☐☐ MONTH ☐☐ DAY
SAMPLE TAKEN

☐☐ CONTRACTOR CODE

SHEET 1 OF 6
BRIDGES
ISSUE 1
BR-F1

Fig. 3

REHABILITATION PLANNING AND COST ESTIMATING PHASE OF THE USRA INVENTORY AND ASSESSMENT PROJECT

By RICHARD P. HOWELL
Vice President and Chief Railroad Engineer
DeLeuw, Cather & Company

All the data elements on the field forms were formatted and coded in such a manner as to enable data processing of all information. However, computerized data processing was limited to track, yard condition, signals and traction power. All other field data was manually reviewed.

In the interest of time here today, we will concentrate on the program for track, as this represents the greatest area of the facility rehabilitation costs.

Identification codes and priority classifications had been assigned to the various routes and lines prior to field inspection. The rehabilitation planning process was also guided by design criteria so that the proper kinds and quantities of material would be utilized. These criteria were determined on the basis of the applicable best-use operating parameters of speed and tonnage as determined between the current 1974 and 1969 Timetables and Traffic Density Charts. This design matrix with three general categories designated (Plate XI) was so developed to be applied in the selection of rail and the determination of other work requirements and components. It should be noted that the FRA classes, as shown, do not constitute a base criteria. These are rejection limits, and measurement criteria for replacement decision were always at least a class higher.

A special computerized program was constructed to provide rapid and accurate translation of the track field conditions and design criteria into rehabilitation work item requirements. A McDonnell Douglas Automation edit program was so adapted and utilized to array the information by sample location.

On Plates XII and XIII we see all historical, visual and measured rail information arrayed with design criteria by milepost location.

Plate XIV shows the necessary planning information concerning tie condition, surface measurement and roadway condition.

With this information, decision logic in regard to rehabilitation planning requirements was readily exercised by the assigned experienced maintenance of way programmers. Rail Renewal (Plate XV), Ballast Work (Plate XVI) illustrate the usual decision process used to determine requirements and aid in the quantification of work items necessary to rehabilitate a track segment to the design standard. It is to be noted that in Trackwork, alone, there were over 50 different work items to be quantified, costed and aggregated. For convenience of assessment and aggregation, 10-mile segments were used and work sheets were formatted accordingly.

All told there were 250 work functions delineated for the planning and estimating phase. Plates XVII through XXV list all these functions and are presented in their entirety to show you the depth and detail of the planning and cost estimating phases. Thus, from track the planning routine continues through Bridges and Tunnels, Signals and Communications, Buildings and Shops, Yards, Servicing Facilities, Traction Power and other Electrical Facility items.

With planning requirements identified, the process of quantification recording continued. Various formats for ease of designating and aggregating the work items were developed and utilized in the project. Plates XXVI and XXVII show track Rehabilitation Work Statement with units designated by intervals of the various required work functions.

Other facility work items were also similarly evaluated and programmed. Plate XXVIII shows a sample printout of a signal and interlocking field report in a coded format which consolidates and arrays the location, quantity and condition of facilities. This informational array along with interlocking and signal diagrams was utilized by signal system rehabilitation planners to quantify, by location, the labor and material items needed.

During the process of establishing unit quantities, unit costs were being developed from:

- Current market prices obtained from vendors, carriers and USRA data.
- Labor rates plus applicable additives similar to standard practices now employed.
- Equipment rental rates at a 10-year straight-line depreciation, examples shown on Plate XXIX.
- Applicable salvage, freight rates and work train expenses.
- Productivity factors based on the Associate Contractors judgement of the operational impacts of the territory which was being rehabilitated.

With this information, unit cost sheets were developed for all work functions. Several samples of this unit cost construction, on an item by item basis, are as follows:

Replacing Rail with New CWR—Plates XXX and XXXI
Cross Tie Renewal—Plate XXXII
Line and Surface in Interlocking—Plate XXXIII
Replacing a Signal Unit—Plate XXXIV
Repair Switch Machine—Plate XXXV

Thus, with the planning, quantification and unit costing phases completed, it then fell to statisticians with their HP-20's to bring these elements together for the aggregate estimates.

This has been a most brief description but hopefully has given you an overview of the process which literally consumed thousands of man hours by the Technical Direction Contractor and Associate Contractors in production of this vast volume of information.

The planning and estimating phases were completed in December and this information along with the volumes of support material were submitted, literally by the boxful, to USRA to be used in their various planning processes.

PLATE XI

TRACKWORK DESIGN

MILLION GROSS TONS PER YEAR	LINE SPEED (MPH)					
	81 to 110	61 to 80	41 to 60	26 to 40	11 to 25	0 to 10
40 & OVER	A	A	A	A	A	▨
30 - 39.9	A	A	A	A	A	▨
20 - 29.9	A	A	A	A	A	▨
10 - 19.9	A	B	B	B	B	B
5 - 9.9	B	B	B	B	B	B
1 - 4.9	B	B	B	C	C	C
0 - 0.9	▨	▨	▨	C	C	C
FRA CLASS OF TRACK	6	5	4	3	2	1

PLATE XII

```
                                         USRA_PROJECT                                          SEGMENT: 039
                                                                                               RR LINE: 4219
                                         10964-001                                             TRACK NUMBER: 2
                                                                                               FACILITY: TR
                                  REVISED TRACKWORK REPORT                  11/11/74           PAGE   74

      MILEPOST                                                          024.0       022.0       020.0

DEGREE CURVATURE                                              |        0.0|        2.5|        0.0
TRACK NUMBER                                                  |          2|          2|          2
RAIL WEIGHT - TRACK CHART                                     |        107|        107|        130
RAIL WEIGHT/SECTION - ACTUAL                                  |      130RE|      130RE|      112RE
YR ROLLED - CONTROL COOLED                                    |     1944CC|     1937--|     1934--
YEAR LAID                                                     |       1900|       1900|       1944
HOW LAID                                                      |   TC ERROR|   TC ERROR|     RELAID
HIGHEST MGT                                                   |        4.5|        4.5|        4.5
HIGHEST SPEED                                                 |         40|         40|         40
DESIGN STANDARD                                               |   DESIGN C|   DESIGN C|   DESIGN C
THEO. MGT OVER RAIL                                           |      129.5|      161.0|      174.5
THEO. LIFE IN MGT                                             |      234.3|      164.7|      235.3
LIFE REMAINING IN MGT                                         |  +  104.8|  +    3.7|  +   60.8
YEARS IN TRACK                                                |         31|         38|         41
THEO. LIFE IN YEARS                                           |         54|         37|         53
REMAINING LIFE IN YEARS                                       |        +23|       - 1|        +12
HEIGHT WEAR ALLOWABLE                                         |      7/16"|      7/16"|      7/16"
HEIGHTWEAR - ACTUAL - HI RAIL                                 |      2/16"|      3/16"|      2/16"
REMAINING HEIGHTWEAR - HI RAIL                                |   + 5/16"|   + 4/16"|   + 5/16"
HEIGHTWEAR - ACTUAL - LOW RAIL                                |      1/16"|      5/16"|      2/16"
REMAINING HEIGHTWEAR - LOW RAIL                               |   + 6/16"|   + 2/16"|   + 5/16"
WIDTH WEAR ALLOWABLE                                          |     14/16"|     14/16"|     12/16"
WIDTH WEAR (GAGE) HI RAIL                                     |      0/16"|      4/16"|      3/16"
REMAINING WIDTH WEAR (GAGE) HI                                |    +14/16"|    +10/16"|   + 9/16"
WIDTH WEAR (FIELD) HI RAIL                                    |      0/16"|      0/16"|      0/16"
REMAINING WIDTH WEAR (FIELD) HI                               |    +14/16"|    +14/16"|    +12/16"
TRANSPOSABILITY - HI RAIL                                     |  TRANSPOSE|  TRANSPOSE|  TRANSPOSE
WIDTH WEAR (GAGE) LOW RAIL                                    |      0/16"|      0/16"|      3/16"
REMAINING WIDTH WEAR (GAGE) LOW                               |    +14/16"|    +14/16"|   + 9/16"
WIDTH WEAR (FIELD) LOW RAIL                                   |      0/16"|      0/16"|      0/16"
REMAINING WIDTH WEAR (FIELD) LO                               |    +14/16"|    +14/16"|    +12/16"
TRANSPOSABILITY - LOW RAIL                                    |  TRANSPOSE|  NOT TRANS|  TRANSPOSE
NUMBER RAIL DEFECTS/MILE                                      |         00|         00|         00
% RAIL REPLACE (BY INSP)                                      |       10 %|       10 %|       20 %
REPLACEMENT REASON                                            |       WEAR|   END BENT|   END BENT
RAIL LAY DECISION STATEMENT                                   |           |           |
                                                              |           |           |

                        FOLLOWING DATA PROVIDED IN EVENT RAIL LAY IS DECIDED

RAIL IN TRACK                                                 |39 BOLTED|39 BOLTED|39 BOLTED
POSSIBLE RAIL DISPOSITION                                     |CROP/RLAY|CROP/RLAY|CROP/RLAY

                        ACCOUNT FOR SALVAGE RAIL AND OTM SCRAP IF RAIL LAY DECIDED
```

PLATE XIII

USRA PROJECT SEGMENT: 039
RR LINE: 4219
10964-001 TRACK NUMBER: 2
FACILITY: TR
REVISED TRACKWORK REPORT 11/11/76 PAGE 78

MILEPOST	024.0	022.0	020.0
ANALYZE DATA ON THIS PAGE ONLY IF OUT-OF-FACE RAIL LAY NOT DECIDED			
ALLOWABLE GAGE	57 3/8"	57 5/8"	57 3/8"
ACTUAL GAGE (MAX)	56 5/8"	57 0/8"	56 4/8"
GAGE DIFFERENCE	+ 0 6/8"	+ 0 5/8"	+ 0 7/8"
RAIL GRINDING	NONE	NONE	NONE
PERCENT WELD/GRIND	20 %	60 %	90 %
NUMBER JOINTS IN SAMPLE	14	14	14
PAIRS BARS REPLACE IN SAMPLE	00	00	00
PERCENT BARS REPLACE	0 %	0 %	0 %
NUMBER JOINTS/MILE	271	271	271
NUMBER BOLTS IN SAMPLE	84	56	56
BOLTS REPLACE IN SAMPLE	18	14	05
PERCENT BOLTS REPLACE	21 %	25 %	9 %
ALLOWABLE MISMATCH - GAGE	2/16"	2/16"	2/16"
ACTUAL MISMATCH (MAX)	0/16"	2/16"	1/16"
MISMATCH DIFFERENCE	+ 2/16"	- 0/16"	+ 1/16"
ALLOWABLE END BATTER	3/8"	3/8"	3/8"
ACTUAL END BATTER (MAX)	1/8"	1/8"	1/8"
END BATTER DIFFERENCE	+ 2/8"	+ 2/8"	+ 2/8"

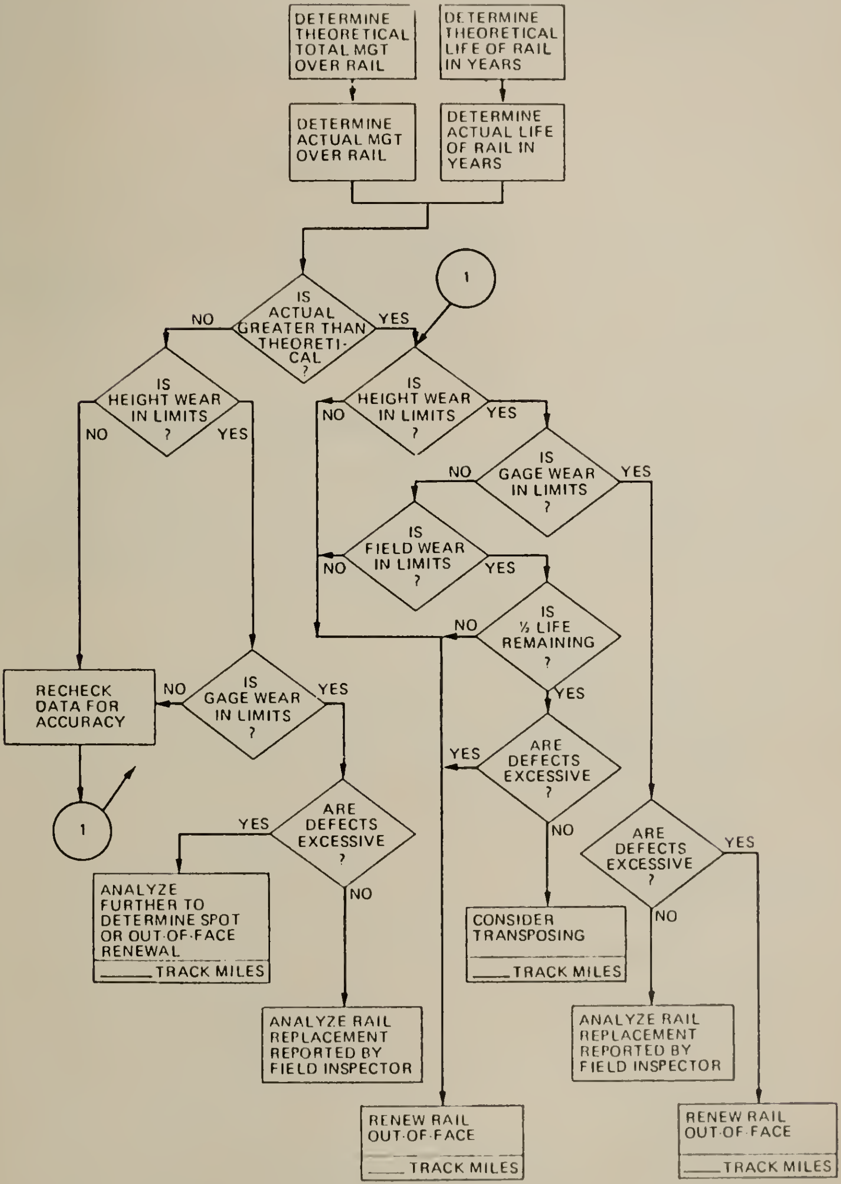
PLATE XIV

USRA PROJECT
10964-001
REVISED TRACKWORK REPORT

SEGMENT: 038
RR LINE: 4219
TRACK NUMBER: 2
FACILITY: TR
11/11/74 PAGE 7C

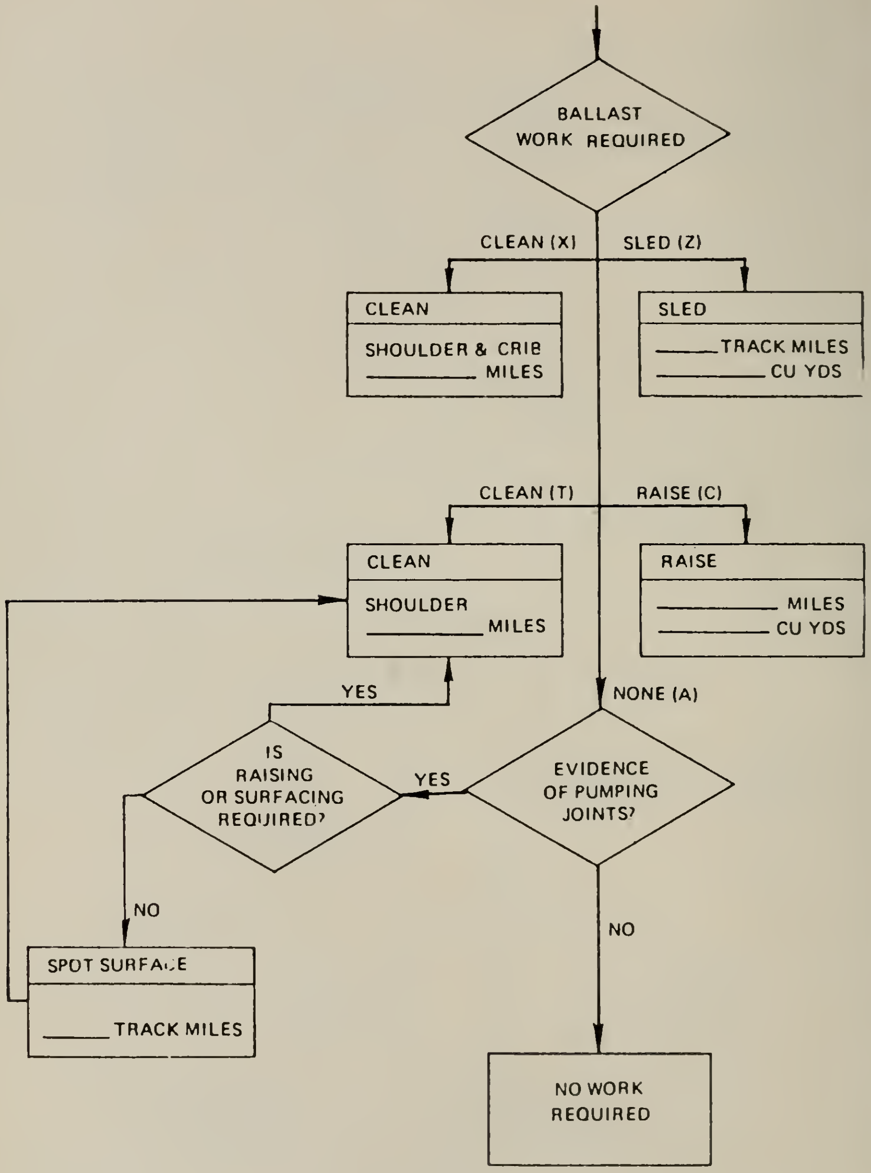
MILEPOST	024.0	022.0	020.0
NUMBER TIES IN SAMPLE	154	154	162
NUMBER BAD TIES	034	041	049
PERCENT TIES REPLACE	22 %	27 %	30 %
NUMBER TIES/MILE TO REPLACE	622	764	848
ALLOWABLE DIST BET SOUND TIES	70"	70"	70"
ACTUAL DISTANCE (MAX)	63"	82"	105"
DISTANCE DIFFERENCE	+ 7"	- 12"	- 35"
ALIGNMENT	SAT	UNSAT	UNSAT
SURFACE	SPOT SURF	OUT/FACE	OUT/FACE
BALLAST WORK	NONE	RAISE	RAISE
PUMPING JOINTS	NO	YES	NO
ALLOWABLE CROSSLEVEL	1 2/8"		1 2/8"
ACTUAL CROSSLEVEL (MAX)	0 3/8"		1 6/8"
DIFFERENCE CROSSLEVEL	+0 7/8"		-0 4/8"
ALLOWABLE SUPERELEVATION		0.0"	
ACTUAL SUPERELEVATION (MAX)	0.0"	5.8"	0.0"
ACTUAL SUPERELEVATION (MIN)	0.0"	5.4"	0.0"
DIFFERENCE SUPERELEVATION (MAX)	-0.0"	-5.8"	-0.0"
DIFFERENCE SUPERELEVATION (MIN)	-0.0"	-5.4"	-0.0"
VEGETATION BALLAST	SPRAY		
VEGETATION SHOULDER	SPRAY	SPRAY	SPRAY
VEGETATION OUTSIDE SHOULDER			
CUT CONDITION			STABLE
FILL CONDITION	STABLE	STABLE	
DITCH CONDITION			FAIR
CULVERT CONDITION			
NO. TIES IN SAMPLE PROP. PLATED	154	151	160
PERCENT TIES PROPERLY PLATED	100 %	98 %	99 %
TIES/MILE NOT PROPERLY PLATED	0	56	28
REQUIRED RAIL HOLDING SPIKES	40	40	40
ACTUAL RAILHOLDING IN SAMPLE	36	28	10
DIFFERENCE - RAILHOLDING SPIKES	- 4	- 12	- 30
ANCHORS PROPERLY APPLIED	NO	NO	YES
ANCHORING EFFECTIVE	YES	NO	YES
SKEWED TIES	05	02	01

PLATE XV


DETERMINE THEORETICAL TOTAL MGT OVER RAIL
DETERMINE THEORETICAL LIFE OF RAIL IN YEARS
DETERMINE ACTUAL MGT OVER RAIL
DETERMINE ACTUAL LIFE OF RAIL IN YEARS
IS ACTUAL GREATER THAN THEORETICAL ?
NO
YES
1
IS HEIGHT WEAR IN LIMITS ?
NO
YES
IS HEIGHT WEAR IN LIMITS ?
NO
YES
IS GAGE WEAR IN LIMITS ?
NO
YES
IS FIELD WEAR IN LIMITS ?
NO
YES
IS ½ LIFE REMAINING ?
NO
YES
RECHECK DATA FOR ACCURACY
IS GAGE WEAR IN LIMITS ?
NO
YES
ARE DEFECTS EXCESSIVE ?
YES
NO
1
ARE DEFECTS EXCESSIVE ?
YES
NO
ARE DEFECTS EXCESSIVE ?
YES
NO
ANALYZE FURTHER TO DETERMINE SPOT OR OUT-OF-FACE RENEWAL
_____ TRACK MILES
CONSIDER TRANSPOSING
_____ TRACK MILES
ANALYZE RAIL REPLACEMENT REPORTED BY FIELD INSPECTOR
ANALYZE RAIL REPLACEMENT REPORTED BY FIELD INSPECTOR
RENEW RAIL OUT-OF-FACE
_____ TRACK MILES
RENEW RAIL OUT-OF-FACE
_____ TRACK MILES

Rail Renewal Analysis

PLATE XVI



Analysis of Ballast Work

PLATE XVII

NOTE - Work Function Codes are to be used as appropriate but in no case is a code number assigned to be used for a work function other than shown. If additional work function codes are required the codes must be assigned by the TDC.

INDEX OF WORK FUNCTIONS

GENERAL WORK FUNCTIONS

	GE 09	Repair Structural Timber	L. F.
	GE 10	Drainage Restoration	S. F.
	GE 11	Chip & Patch Concrete	S. F.
	GE 12	Replace Masonry	S. F.
	GE 01	Point Masonry	SF
	GE 02	Replace Masonry	SF
*	GE 03	Chip and Patch Concrete	SF
*	GE 04	Replace Concrete	CY
	GE 05	Replace Structural Steel	LB
*	GE 06	Clean and Paint Wood	SF
*	GE 07	Clean and Paint Steel	SF
*	GE 08	Weld/Grind Structural Steel	LF (weld)

GE 09 - Repair Structural Timber - L. F.

TRACK WORK FUNCTIONS

	Code	Description	Unit
*	TR 21	Replace Rail With New CWR	Track Mile
*	TR 22	Replace Rail with New Bolted Rail	Track Mile
*	TR 23	Replace Rail with Fit CWR	Track Mile
*	TR 24	Replace Rail with Fit Bolted Rail	Track Mile
*	TR 25	Reposition Rail to Correct Gage	Track Mile
*	TR 26	Transposing Rail	Track Mile
*	TR 27	Grind Rail Surface	Track Mile
*	TR 28	Cross Grind Rail At Joint	Joint
*	TR 29	Weld/Grind Rail End Batter	Joint
*	TR 30	Bolt Renewal/Tightening	Joint
*	TR 31	Joint Bars and Bolt Renewal	Joint
*	TR 32	Field Butt Welds	Weld
*	TR 33	Raise 4" Out of Face	Track Mile
*	TR 34	Surfacing Out of Face (1" to 2" Raise)	Track Mile
*	TR 35	Spot Surfacing	Track Mile
*	TR 36	Line and Surface in Interlockings per Track	Turnout
*	TR 37	Sled Ballast	Track Mile
*	TR 38	Clean Shoulder Ballast (one Side)	Track Mile
*	TR 39	Clean Shoulder Ballast (Both Sides)	Track Mile
*	TR 40	Clean Crib and Shoulder Ballast	Track Mile
*	TR 41	Cross Tie Renewal	Tie

PLATE XVIII

Code	Description	Unit
* TR 42	Switch timber renewal	Timber
* TR 43	Renew frog	Frog
* TR 44	Renew switch points and stock rail	Set
* TR 45	Renew crossing (diamond-4 corners)	Crossing
* TR 46	Renew turnout complete (steel only)	Turnout
* TR 47	Install panelled turnout	Turnout
* TR 48	Weld/grind frog or switch	Each
* TR 49	Weld/grind crossing (diamond - 4 corners)	Each
* TR 50	Vegetation control (spraying brush)	Miles one side
* TR 51	Brush cutting on track	Miles one side
* TR 52	Brush cutting off track	Miles one side
* TR 53	Drainage off track	Miles one side
* TR 54	Drainage on track (ditcher-spreader)	Miles one side
* TR 55	Renew grade crossings	Single track foot
* TR 56	Haul and distribute ballast (surface)	Track Mile
* TR 57	Haul and distribute ballast (raise)	Track Mile
* TR 58	Haul and distribute CWR	Track Mile
* TR 59	Haul and distribute bolted rail	Track Mile
* TR 60	Haul and distribute CWR OTM	Track Mile
* TR 61	Haul and distribute bolted rail OTM	Track Mile
* TR 62	Haul and distribute ties	Tie
* TR 63	Clean up and haul out CWR	Track Mile
* TR 64	Clean up and haul out bolted rail	Track Mile
* TR 65	Clean up and haul out OTM	Track Mile
* TR 66	Clean up and haul out ties	Tie
TR 67	Renew spiking	Spike
TR 68	Renew plates	Plate
TR 69	Regage turnout	Turnout
* TR 70	Haul and distribute panelled turnouts	Turnout
* TR 71	Clean up and haul out turnouts	Turnout
TR 83	Repair R. R. Crossing	Ea.
TR 84	Apply Anchors, bolted rail	T. M.

PLATE XIX

YARD WORK FUNCTIONS

	Code	Description	Unit
*	YA 21	Clean yard track	TF
	YA 22	Repair retarders	EA
	YA 23	Replace retarders	EA
	YA 24	Repair illumination	EA
*	YA 25	Replace illumination	EA
	YA 26	Repair scales	EA
	YA 27	Replace scales	EA

SIGNAL WORK FUNCTIONS

	Code	Description	Unit
*	SI 21	Replace direct buried cable/wire	LF
*	SI 22	Replace ducted cable/wire	LF
*	SI 23	Replace aerial cable/wire	LF
*	SI 24	Replace batteries	EA
*	SI 25	Replace battery housing	EA
*	SI 26	Repair battery housing	EA
*	SI 27	Replace signal unit	EA
*	SI 28	Repair signal unit	EA
*	SI 29	Replace signal mast	EA
*	SI 30	Repair signal mast	EA
*	SI 31	Replace signal foundation	EA
*	SI 32	Replace switch machine	EA
*	SI 33	Repair switch machine	EA
*	SI 34	Replace air lines	LF
*	SI 35	Repair Equip housing	EA
*	SI 36	Replace Equip housing	EA
*	SI 37	Replace relays	EA
*	SI 38	Replace switchlocks	EA
*	SI 39	Replace trunking	LF
*	SI 40	Renew insulated joint	EA
*	SI 41	Renew impedance bonds	EA
*	SI 42	Repair crossing protection flashers	EA
*	SI 43	Renew crossing protection flashers	EA
*	SI 44	Renew crossing gates	EA
*	SI 45	Renew other crossing protection devices	EA
*	SI 46	Replace Signal Mast & Foundation	EA

SI 47 - Replace bootleg and/or track connection - Each
SI 48 - Renew slide protection fence - L. F.
SI 49 - Repair slide protection fence - L. S.
SI 50 - Replace anchors and guys - Each
SI 51 Repair Derail Pipeline Ea.

PLATE XX

BRIDGE WORK FUNCTIONS

Code	Description	Unit
BR 21	Replace marine fenders	LF
BR 22	Replace sheet piling	SF
BR 23	Replace Rip Rap	CY
BR 24	Replace trestle timber	MBF
BR 25	Reapply timber protective coating	MBF
BR 26	Replace bridge ties	Tie
BR 27	Replace bearings	EA
BR 28	Repair mechanical equipment	LS
BR 29	Replace guardrail	Track Foot

TUNNEL WORK FUNCTIONS

Code	Description	Unit
TU 21	Repair ventilation system	Lump sum
TU 22	Renew block ties	Tie
TU 23	Renew guardrail	Track Foot
TU 24	Grout behind lining	Tunnel Foot
TU 25	Install rock bolts	Tunnel Foot
TU 26	Scale loose rock	Tunnel Foot
TU 27	Renew interior lighting	Tunnel Foot
TU 28	Resurface Tunnel Lining	- Tunnel Foot
TU 29	Renew Steel Lining	- Tunnel Foot
TU 30	Clean shoulder ditches	- Tunnel Foot (both sides)

SERVICING FACILITY WORK FUNCTIONS

Code	Description	Unit
SF 21	Repair sand dryer	EA
SF 22	Replace sand dryer	EA
SF 23	Repair sand dispenser	EA
SF 24	Replace sand dispenser	EA
SF 25	Repair water dispenser	EA
SF 26	Replace water dispenser	EA
SF 27	Repair fuel storage tanks	EA
SF 28	Replace fuel storage tanks	EA

PLATE XXI

Code	Description	Unit
SF 29	Repair fuel dispenser	EA
SF 30	Replace fuel dispenser	EA
SF 31	Repair wash rack	EA
SF 32	Replace wash rack	EA
SF 33	Repair turntable	EA
SF 34	Replace turntable	EA
SF 35	Repair lighting equipment	EA
SF 36	Replace lighting equipment	EA
SF 37	Repair cab signal test equipment	EA
SF 38	Repair Environmental Protection Systems	LS
SF 39	Repair caboose servicing equipment	LS

SHOP WORK FUNCTIONS

Code	Description	Unit
SH 21	Repair platforms	LF
SH 30	Repair major supporting machinery	EA
SH 40	Replace major supporting machinery	EA
SH 50	Repair peripheral machinery	EA
SH 60	Replace peripheral machinery	EA

BUILDING WORK FUNCTIONS

Code	Description	Unit
BL 21	Repair plumbing	SF
BL 22	Repair electrical	SF
BL 23	Repair HVAC System	SF
BL 24	Repair flooring	SF
BL 25	Repair ceiling	SF
BL 26	Repair roofing	SF
BL 27	Repair windows	SF
BL 28	Repair interior walls	SF
BL 29	Repair parking area	SY
BL 30	Repair exterior lighting	SF
BL 31	Repair Environmental Protection Systems	LS
BL 32	Repair fence	LF

BL 33 - Replace doors - Each
BL 34 - Replace siding - SF

PLATE XXII

FREIGHT TERMINAL WORK FUNCTIONS

Code	Description	Unit
FT 21	Repair parking/storage area	SF
FT 22	Repair gantry	EA
FT 23	Repair sidelift	EA
FT 24	Repair sideslips	EA
FT 25	Repair hostling tractors	EA
FT 26	Repair scales	EA
FT 27	Repair bulk transfer equipment	EA
FT 28	Repair ramps	EA
FT 29	Repair lighting equipment	EA
FT 30	Replace lighting equipment	EA

MARINE TERMINAL WORK FUNCTIONS

Code	Description	Unit
MT 22	Replace pile spring line	LF
MT 23	Repair dock	LF
MT 24	Repair float bridge	EA
MT 25	Replace float bridge	EA
MT 26	Repair bridge hoisting machinery	EA
MT 27	Replace bridge hoisting machinery	EA
MT 28	Dredging	CY
MT 29	Repair lighting equipment	EA
MT 30	Replace lighting equipment	EA
MT 31	Repair bulk unloaders (i. e., ore)	EA
MT 32	Replace bulk unloaders	EA
MT 33	Repair bulk loaders (i. e., coal)	EA
MT 34	Replace bulk loaders	EA
MT 35	Repair live storage facility	EA
MT 36	Replace live storage facility	EA
MT 37	Repair scales	EA
MT 38	Repair Environmental Protection Systems	LS

PLATE XXIII

TRACTION POWER WORK FUNCTIONS

CODE	DESCRIPTION	UNIT
EL 21	Clean & Paint Catenary Support	EA
EL 22	Replace Catenary Support	EA
EL 23	Replace Guy Wire & Stub	EA
EL 24	Replace Catenary Insulators	EA
EL 25	Replace Catenary Messenger Wire	TM
EL 26	Replace Catenary Auxiliary Wire	TM
EL 27	Replace Catenary Trolley Wire	TM
EL 28	Replace Body/Steady/Cross Wire	LF
EL 29	Replace Catenary Hardware	TM
EL 30	Repair Cat. Sectionalizing Switches	EA
EL 31	Replace Cat. Feeder Hardware	STA
EL 32	Clean Cat. Pole Foundation	EA
EL 33	Repair Cat. Pole Foundation	EA
EL 34	Repair Catenary Support	EA
EL 35	Clean and Paint Catenary Structure	EA
EL 36		
EL 37		
EL 38		
EL 39		
EL 40	Replace 3rd Rail Insulators	EA
EL 41	Replace 3rd Rail Contact Rail	TM
EL 42	Replace 3rd Rail Support Ties	TIE

PLATE XXIV

OTHER ELECTRICAL WORK FUNCTIONS

CODE	DESCRIPTION	UNIT
OE 21	Repair fencing	LF
OE 22	Repair disconnect switches	EA
OE 23	Replace disconnect switches	EA
OE 24	Repair circuit breakers	EA
OE 25	Replace circuit breakers	EA
OE 26	Repair transformers	EA
OE 27	Replace transformers	EA
OE 28	Repair rectifiers	EA
OE 29	Replace rectifiers	EA
OE 30	Repair frequency converters	EA
OE 31	Replace frequency converters	EA
OE 32	Repair power bus	EA
OE 33	Replace power bus	EA
OE 34	Repair pole mounted transformer	EA
OE 35	Repair slab mounted transformer	EA
OE 36	Repair Substation Superstructure	EA
OE 37	Replace 15 KV High Voltage Cable	LF
OE 38	Replace 600 V High Voltage Cable	LF
OE 39	Install Illumination	UNIT
OE 40	Vegetation Control	SF
OE 41	Replace 600 V Control Wire	EA
OE 42	Repair Signal & Svc Station Transformers	EA
OE 43	Replace Batteries	STA
OE 44	Replace Grounding Grid	STA
OE 45	Repair Access Road	STA
OE 46	Clean & Paint Control Bldg.	STA
OE 47	Replace Battery Chargers	EA

PLATE XXV

COMMUNICATIONS

Code	Description	Unit
CO 21	Replace pole	EA
CO 22	Replace cross arms	EA
CO 23	Replace insulators	EA
CO 24	Replace guy wires	EA
CO 25	Repair receiver/transmitter	EA
CO 26	Replace receiver/transmitter	EA
CO 27	Repair base station	EA
CO 28	Replace base station	EA
CO 29	Repair telephone system equipment	LS

CO 30 - Adjust Guy Wires - Each
CO 31 - Adjust Line Wires - LF

NOTE:

* All work functions with an asterisk have RW-F5 work function code sheets furnished with suggested unit costs. For all work function codes without an asterisk, no RW-F5 has been furnished. Types, sizes, and field conditions vary so greatly that it is impractical to establish a standard unit cost applicable in all cases. Therefore, Associate Contractors will develope the remaining work function codes on an individual basis in accordance with the format and procedures as established on the RW-F5's furnished.

PLATE XXVI

CONTRACTOR CODE 1 DC DATA CARD NUMBER 3 11
PREPARED BY AWM DATE ______
APPROVED BY ______ DATE ______
REVIEWED BY ______ DATE ______

REHABILITATION WORK STATEMENT

LINE SPEED 79 MGT 8.3 DESIGN B

FACILITY CODE TR
OPERATIONAL SEGMENT 8 B03
LINE CODE 6 42019
FACILITY NAME ______

LOCATION (GROUPED BY FACILITY)		RAIL RENEWAL				OTHER RAIL WORK				JOINTS NOTE ①				SALVAGE			TIES	
TRACK NUMBER		NEW CWR	NEW BOLTED	FIT CWR	FIT BOLTED	CORRECT GA	TRANSPOSE	GRIND SURFACE	CROSS GRIND	WELD GRIND END BATTER	BOLT RENEWAL	BAR RENEWAL	FIELD BUTT WELD	FIT SALVAGE RAIL	SCRAP SALVAGE RAIL	SALVAGE OTM	TIE RENEWAL	
MILEPOST	INTERVAL	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	JOINT	JOINT	JOINT	JOINT	WELD	WEIGHT TRACK MILE	TONS	TONS	TIE	
TRACK	No.1.	(TR)																
73-		119RE			131RE		131RE							131 RE	131 RE	[illegible]		
- 80	7.0	1.2			0.35		0.35	4.0	—	523	718	—		1.15	92	168	8193	
80 -																		
- 90	10.0	—						4.0	1084	379	1084						7506	
90-																		
- 100	10.0	—	-	-	.	8.0	—	—	—	—	—	—					10510	
100 -																		
- 110	10.0	—				2.0	-	2.0	-	54	—	-					9140	
110 -																		
- 120	10.0	—				—			1084	325	1626	—					11426	
120-					131RE		131RE							131 RE	131 RE	131 RE		
- 122.8	2.8	—			0.40		0.40	—	—	—	—			0.30	23	43	5452	
TRACK	No. 2	(TR)																
73-																		
- 80	7.0	—	—	—	—	-	-	6.0	—	189	—	—	—	—	-	.	6070	
80 -																		
- 90	10.0	—	—	—	-	4.0	—	10.0	—	—	542	—	—	—	-	-	12664	
90 -																		
-100	10.0	—	-	—	-	8.0	—	—	—	—	—	—	—	—	—	—	11882	
100 -																		
- 110	10.0	—	—	—	-	4.0	—	—	—	—	—	—	—	—	-	-	10900	
110 -																		
- 120	10.0	—	-	-	-	4.0	—	10.0	—	-	-	-	—	—	—	—	11356	
120 -																		
- 122.8	2.8	—	-	—		2.8	—	—	—	—	—	—	—	-	—	-	1736	
TRACK	No 5	(TR)	— 30 MPH -		MGT· 4.4 — DESIGN C													
212-																		
-105.1	3.9		-		..	—	-	1.5	768	40	—	—	—	—	—	—	5678	
TRACK	No 6	(TR)	— 30 MPH -		MGT-4.4 - DESIGN C													
101.2-					131#									100#	100#	100#		
-105.5	4.3				0.80	-	—	3.5	—	664	—	199	—	0.60	36	45	7658	
	107.8	12 1.2	16	20	24 1.55	28 32.8	32 0.75	36 41.0	40 2336	46	52 3970	58 199	64 68	12 2.05	17 151	23 256	29 120201 35	
TOTAL		1			2	33	1	41	2336	2174	3970			2	151	256	120201	
WORK	FUNCTION	TR 21	TR 22	TR 23	TR 24	TR 25	TR 26	TR 27	TR 28	TR 29	TR 30	TR 31	TR 32	YY 97	YY 98	YY 99	TR 41	

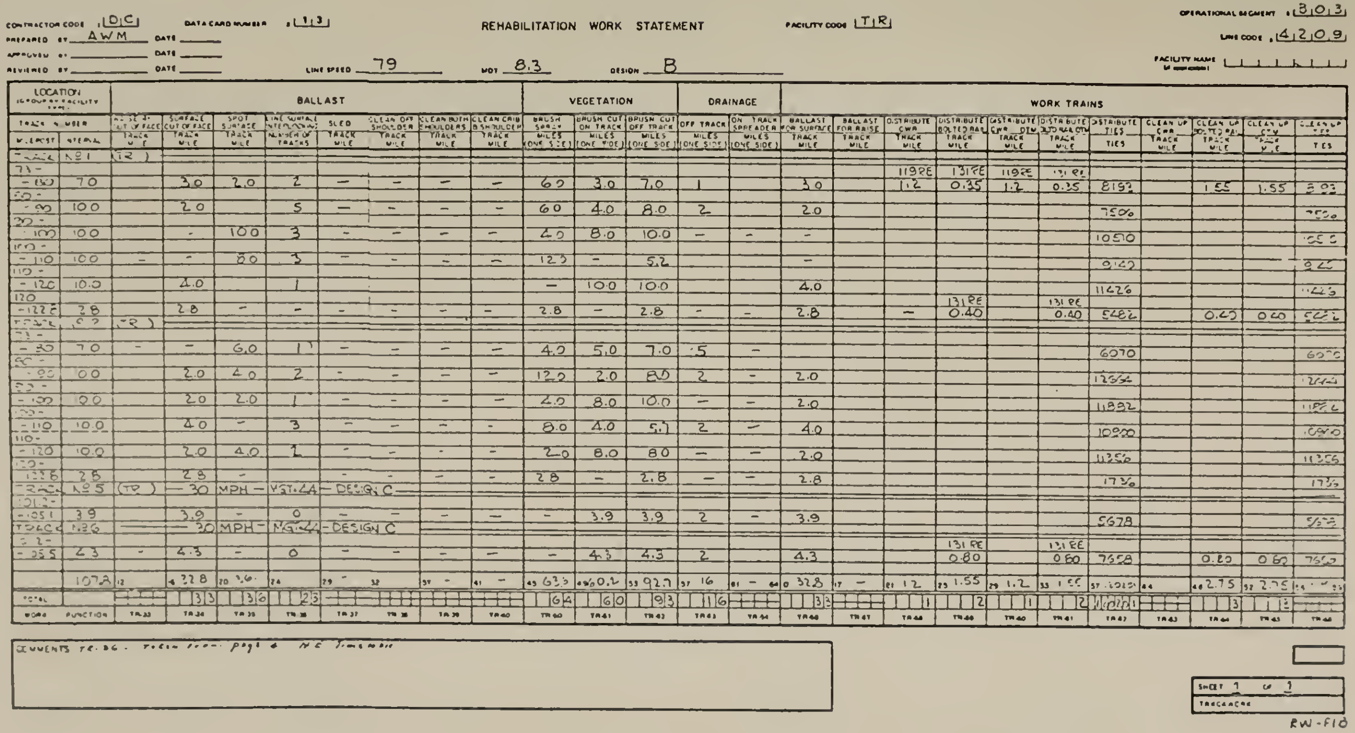
RAIL INSTALLATION SUMMARY

RAILWEIGHT	131 RE	119 RE	100#								WORK FUNCTION
TRACK MILES NEW RAIL IN		1.20									TR 21/22
TRACK MILES FIT RAIL IN	1.55										TR 23/24
TRACK MILES FIT RAIL OUT	1.45		0.60								YY 97
[illegible]	0.50		0.20								YY 98

NOTE ① OTHER THAN WITH RAIL RENEWAL

SHEET 1 OF 1
TRACKWORK

PLATE XXVII



CONTRACTOR CODE DC
PREPARED BY AWM DATE
APPROVED BY DATE
REVIEWED BY DATE
DATA CARD NUMBER 113

REHABILITATION WORK STATEMENT

LINE SPEED 79
MGT 8.3
DESIGN B
FACILITY CODE TR
OPERATIONAL SEGMENT 303
LINE CODE 4209
FACILITY NAME (IF APPLICABLE)

LOCATION (GROUP BY FACILITY TYPE)		BALLAST								VEGETATION			DRAINAGE		WORK TRAINS										
TRACK NUMBER		RAISE & CUT OF FACE	SURFACE CUT OF FACE	SPOT SURFACE	LINE SURFACE INTERLOCKING	SLED	CLEAN OFF SHOULDER	CLEAN BOTH SHOULDERS	CLEAN CRIB & SHOULDER	BRUSH SPRAY	BRUSH CUT ON TRACK	BRUSH CUT OFF TRACK	OFF TRACK	ON TRACK SPREADER	BALLAST FOR SURFACE	BALLAST FOR RAISE	DISTRIBUTE CWR	DISTRIBUTE BOLTED RAIL	DISTRIBUTE CWR OTM	DISTRIBUTE BOLTED RAIL OTM	DISTRIBUTE TIES	CLEAN UP CWR	CLEAN UP BOLTED RAIL	CLEAN UP OTM	CLEAN UP TIES
MILEPOST	NOMINAL	TRACK MILE	TRACK MILE	TRACK MILE	NUMBER OF TRACKS	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	MILES (ONE SIDE)	MILES (ONE SIDE)	MILES (ONE SIDE)	MILES (ONE SIDE)	MILES (ONE SIDE)	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	TRACK MILE	TIES	TRACK MILE	TRACK MILE	TRACK MILE	TIES
Track	No 1	(TR)																							
71-																	119RE	131RE	119RE	131RE					
-80	70		3.0	2.0	2	–	–	–	–	6.0	3.0	7.0	1		3.0		1.2	0.35	1.2	0.35	8192		1.55	1.55	8192
80-																									
-90	100		2.0		5	–	–	–	–	60	4.0	8.0	2		2.0						7506				7506
90-																									
-100	100		–	100	3	–	–	–	–	4.0	8.0	10.0	–	–	–						10510				10510
100-																									
-110	100	–	–	80	3	–	–	–	–	12.3	–	5.2			–						9142				9142
110-																									
-120	10.0		4.0		1					–	10.0	10.0			4.0						11426				11426
120																		131RE		131RE					
-122.6	2.8		2.8	–	–	–	–	–	–	2.8	–	2.8	–	–	2.8		–	0.40		0.40	5482		0.40	0.40	5482
Track	No 2	(TR)																							
71-																									
-80	7.0	–	–	6.0	1	–	–	–	–	4.0	5.0	7.0	.5	–							6070				6070
80-																									
-90	10.0		2.0	4.0	2	–	–	–	–	12.0	2.0	8.0	2	–	2.0						12654				12644
90-																									
-100	10.0		2.0	2.0	1	–	–	–	–	4.0	8.0	10.0	–	–	2.0						11892				11892
100-																									
-110	10.0		4.0	–	3	–	–	–	–	8.0	4.0	5.1	2	–	4.0						10920				10920
110-																									
-120	10.0		2.0	4.0	1	–	–	–	–	2.0	8.0	8.0	–	–	2.0						11356				11356
120-																									
-122.6	2.5		2.8	–		–	–	–	–	2.8	–	2.8	–	–	2.8						1736				1736
Track	No 5	(TR)	— 30	MPH —	YST.44 —	DESIGN C —																			
101.2-																									
-105.1	3.9		3.9	–	0	–	–	–	–	–	3.9	3.9	2	–	3.9						5678				5678
Track	No 6	———	— 30	MPH —	NG.44 —	DESIGN C																			
51.2-																		131RE		131RE					
-55.5	4.3	–	4.3	–	0	–	–	–	–	–	4.3	4.3	2		4.3			0.80		0.80	7558		0.80	0.80	7558
	107.8	12	16 32.8	20 36.0	24	29 –	32	37 –	41 –	45 63.3	49 60.2	53 92.7	57 16	61 – 64	0 32.8	17 –	21 1.2	25 1.55	29 1.2	33 1.55	37 [illegible]	44	48 2.75	52 2.75	56 [illegible]
TOTAL			33	36	23					64	60	93	16		33		1	2	1	2	[illegible]		3	3	
WORK	FUNCTION	TR 33	TR 34	TR 35	TR 36	TR 37	TR 38	TR 39	TR 40	TR 40	TR 41	TR 42	TR 43	TR 44	TR 46	TR 47	TR 48	TR 49	TR 40	TR 41	TR 42	TR 43	TR 44	TR 45	TR 46

COMMENTS TR. 36 - Taken from page 4 NE Timetable

SHEET 1 OF 1
TRACKAGE

RW-F10

PLATE XXVIII

```
                              USRA PROJECT                                  RR LINE 2402
                               10964-001
                 INTERLOCKINGS & SIGNALS-SAMPLE REPORT                      FACILITY: SI1
                               HONEYBEAR
                                                                                  6/4/74

                                                                              PAGE  1

DESCRIPTION.............. SIGNALS........................... SWITCHES....... MISCEL...........................................
1            2  3 4 5  6  7 1 2  3  4  5 6 7 8 9 A B  C D 1  2  3 4 5 6 1 2   3  4  5 6  7 8 9 A  B C  D E F G

CP        82.8  8 L E 18 10 A P 14 50 16 2 0 1 0 2 0  5 A 0 13  0 2 1 0 1 0   0  0  0 1 10 0 0 0  0 A  8 0 0 1
          88.9              A P        2 0 0 1 0 0      A               0 0      0    1  0 1 0    0 Z  4     1
FAIRHPE   96.8 11 L E 22 68 A P  4 10 21 2 1 1 0 1 1  5 A 0  0 17 2 0 1 1 0   0 50 50 2  3 1 0 0  0 A 10 0 0 1
          99.3              A P        7 1 0 0 0 0      Z               1 0      0    0  0 0 1    0 A  3     1
WANDLE   101.3 10 L R 10 25 A P  0  0 13 1 0 0 0 0 0  0 A 0  1  0 0 0 0 0 0   0  0  0 1  1 0 0 0  0 A  3 0 0 1
MCKINLY  102.1  9 L E 17 10 A P  3 10 16 2 0 1 1 0 0  0 A 0  0 14 2 0 1 1 0 200  0 10 2  3 1 0 0  0 A  0 0 0 1
REED     105.4  6 R R  7 23 A P  2  8  7 0 0 1 0 0 0  2 Z 0  5  0 0 0 0 1 0   0  0  0 0  1 0 0 0 10 A  0 0 0 1
         108.1              A P        2 0 0 1 0 0      A               0 1     50    1  3 1 0    0 A  2     1
MALE     110.7  9 L E 13  5 A P 11 71 13 1 1 0 1 1 0  2 A 0  0  9 0 1 0 0 1 100 80 25 0 10 1 0 0  0 Z  5 0 0 1
         122.7              A P        2 0 0 0 0 0      A               0 0      0    0  5 1 0    0 Z  2     1
ORRULLE  124.0  7 L E 11 17 A P 16 75 13 2 0 1 0 0 1  8 A 0  0  8 2 1 1 1 0  85  0  0 1  2 0 0 0  0 A  2 0 0 1
```

PLATE XXIX

CODES	HOURLY RATES	DESCRIPTION
76	$ 1.14	Backhoe
77	$ 0.13	Push Car - 30,000#
78	$ 0.03	Push Car - 10,000#
79	$ 0.02	Push Car - 5,000#
80	$ 0.05	Portable Generator w/Floodlamps
81	$ 3.17	Brush Cutter (On Track)
82	$ 2.29	Brush Cutter (Off Track)
83	$215.90	Crib and Shoulder Ballast Cleaner (Contract)
84	$ 0.18	Spike Puller (Light Duty)
85	$ 0.16	Hydraulic Rail Puller-Expander
86	$ 0.69	Rail Heater
87	$ 0.19	Asphaltic Concrete Compactor
88	$ 0.06	Air Impact Wrench (Light Duty)
89	$ 0.19	Track Wrench (Light Duty Bolt Tightener)
90	$ 2.60	Bulldozer
91	$ 16.57	Concrete Pump
92	$ 0.09	Cross Grinder Slotter
93	$ 3.32	Tie Destroyer
94	$ 5.35	Hi Rail Hydra Crane
95	$ 0.31	Stub Driver
96	$ 0.10	Bond Welder
97	$ 6.87	Ditcher Spreader
98	$ 16.57	150 ton Crane (Truck)
99	$ 1.70	50 c.y. Air Dump Car
6A	$ 1.40	Cherry Picker, truck mounted, 3 Ton w/ insulated Bucket & Arm

NOTE: Equipment rates researched from Vendors, 3rd Quarter, 1974, Life expectancy of equipment set at 10 years.

PLATE XXX

REHABILITATION ESTIMATE WORK SHEET

ESTIMATOR ______
ASSOCIATE CONTRACTOR ______
WORK FUNCTION Replace rail with new CWR
DATE ______
JOB NO. ______
SHEET NO. 1 of 2
WORK FUNCTION CODE TR 21

ASSUMPTIONS

UNIT OF WORK
Track Mile

1 100% Railroad forces, 10 hour straight time shifts, 8 hours track time, no travel time.
2 Mechanized operation @ a rate of one track mile laid in 16 hours track time.
3 Rail and O.T.M. previously unloaded on shoulder.
4 All O.T.M. new.
5 Ties adzed and sprayed with preservative.
6 Spike holes plugged and redrilled.
7 Tie spacing @ 19½" centers.
8 Eight insulated joints per mile.
9

COST PER Track Mile			
TRACK TIME	20 HRS	16 HRS	12 HRS
LABOR	6365	7955	10,605
EQUIPMENT	775	970	1,295
COMMODITY	96720	96720	96,720
TOTAL	103,860	105,645	108,620

LABOR							EQUIPMENT							COMMODITY				
CODE	CLASSIFICATION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	DESCRIPTION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	TOTAL AMOUNT	UNIT	UNIT PRICE	TOTAL DOLLARS
M3	General Foreman	1	20	20	6.97	139.40	41	Burro crane	2	40	40	5.61	224.40	AA	10,560	LF	5.60	59136.00
T1	Foreman	4	80	80	5.58	446.40	12	Spike puller(heavy duty)	2	40	40	0.41	16.40	AK	6,500	EA	2.38	15470.00
T3	Craftsman	7	140	140	5.43	760.20	35	Bolt tightener(heavy duty)	2	40	40	2.32	92.80	AI	20,200	EA	0.17	3434.00
T4	Machine Operator	22	440	440	5.30	2332.00	46	Scrap loader	2	40	40	0.80	32.00	AJ	10,000	EA	0.675	6750.00
T5	Laborer	44	880	880	4.59	4039.20	95	Stub driver	1	20	20	0.31	6.20	AG	8	EA	135.00	1080.00
S1	Signal Maintainer	1	20	20	5.98	119.60	29	Ballast cribber	2	40	40	0.57	22.80	DR	10,560	LF	0.86	9081.00
S2	Signalman	1	20	20	5.83	116.60	02	Tie plug inserter	2	40	40	0.28	11.20	DU	16	EA	30.00	480.00
							03	Tie adzer	2	40	40	1.76	70.40	DN	160	EA	8.00	1280.00
							06	Tie sprayer	1	20	20	0.14	2.80	DV	8	EA	1.04	8.32
							16	Gager	1	20	20	0.65	13.00					
							22	Squeeze tamper w/jacks	1	20	20	2.27	45.40					
							15	Spike cart	1	20	20	0.43	8.60					
							33	Anchor cart	1	20	20	0.43	8.60					
							05	Duel tie drill	2	40	40	0.21	8.40					
							86	Rail heater	1	20	20	0.69	13.80					
							25	Air compressor	1	20	20	0.69	13.80					
							32	Anchor applicator	2	40	40	0.52	20.80					
							96	Bond welder	1	20	20	0.10	2.00					
							77	Push car - 30,000#	5	100	100	0.13	13.00					
							20	Rail saw	1	20	20	0.05	1.00					
							19	Rail drill	1	20	20	0.04	.80					
					TOTAL	$7953.40						SUB TOTAL	628.20				TOTAL	$96,719.92

RW-F5

PLATE XXXI

REHABILITATION ESTIMATE WORK SHEET

ESTIMATOR ______
ASSOCIATE CONTRACTOR ______
WORK FUNCTION Replace rail with new CWR (cont.)
DATE ______
JOB NO. ______
SHEET NO. 2 of 2
WORK FUNCTION CODE TR 21

ASSUMPTIONS

UNIT OF WORK

COST PER			
TRACK TIME	HRS	HRS	HRS
LABOR			
EQUIPMENT			
COMMODITY			
TOTAL			

1 ______
2 ______
3 ______
4 ______
5 ______
6 ______
7 ______
8 ______
9 ______

LABOR							EQUIPMENT								COMMODITY				
CODE	CLASSIFICATION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	DESCRIPTION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	TOTAL AMOUNT	UNIT	UNIT PRICE	TOTAL DOLLARS
							49	Surface grinder	1	20	20	0.11	2.20					
							50	Flexible grinder	1	20	20	0.06	1.20					
							85	Hydraulic rail puller, expander	1	20	20	0.16	3.20					
							66	Fuel & lube truck	1	20	20	0.47	9.40					
							64	Passenger bus	2	40	40	0.47	18.80					
							63	Mechanic truck	1	20	20	0.24	4.80					
							67	6 man hyrail pickup truck	1	20	20	0.28	5.60					
							60	Rail camp train	1	20	20	14.71	294.20					
							65	Sedan w/A.C.	1	20	20	0.21	4.20					
								Subtotal sh. 1					628.20					
					TOTAL							TOTAL	971.80				TOTAL	

RW-F5

PLATE XXXII

REHABILITATION ESTIMATE WORK SHEET

ESTIMATOR ______
ASSOCIATE CONTRACTOR ______
WORK FUNCTION Cross tie removal
DATE ______
JOB NO. ______
SHEET NO. 1 of 1
Revised 9/26/74
WORK FUNCTION CODE TR 41

ASSUMPTIONS

1 100 Railroad forces, 10 hour straight time shifts, 8 hours track time, no travel time.
2 Mechanized operation @ a rate of 400 ties replaced per 8 hours track time.
3 Standard cross ties, 7" x 9" x 8'-6" @ 19½" centers, doweled and treated
4 Ties and spikes new. Remaining OTM Fit for reuse.
5 All commodities previously delivered to the work site.
6
7
8
9

UNIT OF WORK
Cross Tie

COST PER Cross Tie			
TRACK TIME	10 HRS	8 HRS	6 HRS
LABOR	3.86	4.82	6.43
EQUIPMENT	0.70	0.87	1.17
COMMODITY	15.33	15.33	15.33
TOTAL	$19.89	$21.02	$22.93

LABOR

CODE	CLASSIFICATION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS
M2	Assistant Supervisor	1	10	0.025	7.05	0.176
T1	Foreman	1	10	0.025	5.58	0.140
T3	Craftsman	5	50	0.125	5.43	0.679
T4	Machine Operators	13	130	0.325	5.30	1.723
T5	Laborers	17	170	0.425	4.59	1.951
S1	Signal Maintainer	1	10	0.025	5.98	0.150
					TOTAL	$4.819

EQUIPMENT

CODE	DESCRIPTION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS
12	Spike puller(heavy duty)	2	20	0.050	0.41	0.021
10	Tie shear	1	10	0.025	1.85	0.046
11	Tie bed scarifier	1	10	0.025	1.66	0.042
93	Tie destroyer	1	10	0.025	3.32	0.083
07	Tie handler	2	20	0.050	9.99	0.050
09	Tie inserter	1	10	0.025	2.79	0.070
22	Squeeze tamper w/jacks	1	10	0.025	2.27	0.057
05	Dual tie drill(heavy duty)	2	20	0.050	0.21	0.011
14	Dual spike driver (H.O.)	2	20	0.050	1.89	.09
18	Rail lifter	1	10	0.025	0.90	0.023
66	Fuel and lube truck	1	10	0.025	0.47	0.012
64	Passenger bus	2	20	0.050	0.47	0.024
68	Truck type station wagon	1	10	0.025	0.21	0.005
67	6 man hi rail pickup trk.	1	10	0.025	0.28	0.007
65	Sedan w/A.C.	1	10	0.025	0.21	0.005
59	T&S camp car train	1	10	0.025	12.40	0.310
96	Bond welder	1	10	0.025	0.10	0.003
63	Mechanic truck	1	10	0.025	0.24	0.006
					TOTAL	$0.864

COMMODITY

CODE	TOTAL AMOUNT	UNIT	UNIT PRICE	TOTAL DOLLARS
AI	2480	6.2	0.17	1.05
AP	400	1	13.50	13.50
ON	38	0.095	8.00	0.76
DV	8	0.020	1.04	0.02
			TOTAL	$15.33

RW-FS

PLATE XXXIII

REHABILITATION ESTIMATE WORK SHEET

ESTIMATOR ____________
ASSOCIATE CONTRACTOR ____________
WORK FUNCTION Line & Surface in Interlockings per track
DATE ____________
JOB NO. ____________
SHEET NO. 1 of 1
WORK FUNCTION CODE TR 36

ASSUMPTIONS

UNIT OF WORK
Turnout

1 100% Railroad Forces, 8 hour straight time shifts, 6 hours track time, no travel time.
2 Mechanized/Manual Operation @ rate of 2 turnouts per 6 hours track time.
3 Skin Raise only, ample ballast @ site.
4
5
6
7
8
9

COST PER Turnout			
TRACK TIME	8 HRS	6 HRS	4 HRS
LABOR	202	270	405
EQUIPMENT	12	16	24
COMMODITY	210	210	210
TOTAL	424	496	274

LABOR							EQUIPMENT							COMMODITY				
CODE	CLASSIFICATION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	DESCRIPTION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	TOTAL AMOUNT	UNIT	UNIT PRICE	TOTAL DOLLARS
T1	Foreman	1	8	4	5.58	22.32	23	Switch Tamper w/Jacks	1	8	4	2.25	9.00	DP	14	7	$30.00	$210.00
T2	Assistant Foreman	1	8	4	4.96	19.84	25	250 CFM Compressor	1	8	4	0.69	2.76					
T4	Machine Operator	1	8	4	5.30	21.20	24	Air Hand Tampers	8	64	32	0.05	1.60					
T5	Laborer	10	80	40	4.59	183.60	62	6-Man Utility Truck	2	16	8	0.24	1.92					
S1	Signal Maintainer	1	8	4	5.98	23.92	65	Sedan w/A.C.	1	8	4	0.21	0.84					
					TOTAL	$270.88						TOTAL	$16.12				TOTAL	$210.00

RW-F5

PLATE XXXIV

REHABILITATION ESTIMATE WORK SHEET

ESTIMATOR ______
ASSOCIATE CONTRACTOR ______
WORK FUNCTION Replace Signal Unit
DATE ______
JOB NO. ______
SHEET NO. 1 of 1
WORK FUNCTION CODE SI - 27

ASSUMPTIONS

1 100% Railroad forces, 8 hours straight time shift, 6 hour track time, No travel time
2 Signal unit to be mounted on mast @ rate of one Signal Unit per 6 hrs track time
3 Includes Testing
4
5
6
7
8
9

UNIT OF WORK
Each

COST PER	Each		
TRACK TIME	8 HRS	6 HRS	4 HRS
LABOR	100	130	200
EQUIPMENT	1	2	3
COMMODITY	835	835	835
TOTAL	$936	$967	$1038

LABOR							EQUIPMENT							COMMODITY				
CODE	CLASSIFICATION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	DESCRIPTION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	TOTAL AMOUNT	UNIT	UNIT PRICE	TOTAL DOLLARS
S1	Signalman Maintainer	1	8	8	5.98	47.84	62	6 Man utility truck	1	8	8	0.24	1.92	KD	1	1	745.00	745.00
S2	Signalman	1	8	8	5.83	46.64								DP	3	3	30.00	90.00
S3	Signalman Helper	1	8	8	4.74	37.92												
					TOTAL	$132.40						TOTAL	$1.92				TOTAL	$835.00

RW-F5

PLATE XXXV

REHABILITATION ESTIMATE WORK SHEET

ESTIMATOR ______
ASSOCIATE CONTRACTOR ______
WORK FUNCTION Repair Switch Machine
DATE ______
JOB NO. ______
SHEET NO. 1 of 1
WORK FUNCTION CODE S1-33

ASSUMPTIONS

1 100% Railroad forces, 8 hours straight time shifts, 6 hours track time, no travel time
2 Replace broken or worn parts - clean - lubricate and paint
3 Repair one switch machine per 6 hours track time
4
5
6
7
8
9

UNIT OF WORK
Each

COST PER	Each		
TRACK TIME	8 HRS	6 HRS	4 HRS
LABOR	135	180	270
EQUIPMENT	1	2	3
COMMODITY	820	820	820
TOTAL	$956	$1002	$1093

LABOR							EQUIPMENT							COMMODITY				
CODE	CLASSIFICATION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	DESCRIPTION	NO REQ	TOTAL HOURS	UNIT HOURS	HOURLY RATE	TOTAL DOLLARS	CODE	TOTAL AMOUNT	UNIT	UNIT PRICE	TOTAL DOLLARS
S1	Signal Maintainer	1	8	8	5.98	47.84	62	6 Man Utility Truck	1	8	8	0.24	1.92	KR	1	1	700.00	700.00
S2	Signalman	2	16	16	5.83	93.28								DP	4	4	30.00	120.00
S3	Signalman helper	1	8	8	4.74	37.92												
					TOTAL	$179.04						TOTAL	$1.92				TOTAL	$820.00

AW-F5

Heavy Cars—What Are the Issues?

76–653–14

By G. H. WAY
Assistant to Vice President, Research and Test Department
Association of American Railroads

It is a pleasure for me to be here this morning to share some thoughts on car size with the many friends and professional associates I have come to know who are members of this Association.

I am somewhat reluctant to speak on the subject of heavy cars. This reluctance stems from a number of reasons. Probably the most significant of these is that much already has been said and written on this subject and very little has been done. I do not want merely to add to the many words without an equal contribution to action.

The railway engineering profession is in danger, with respect to this issue, of being likened to the boy who cried wolf. Over the years, we have protested increases in wheel load and we have predicted dire consequences if such increases were adopted. Because some of those consequences were not realized immediately, or in as short a period of time as was forecasted, our credibility has suffered.

It is not my purpose to launch another "witch hunt" against heavy cars, nor to examine in technical detail the consequences of their operation. In the first place, such a technical examination, I feel, could be done better by others. Secondly, based on the evidence at hand, I am neither certain that a witch hunt would be successful, nor that it should be. Lastly, there is not much point in stressing to this audience the adverse effects on track of heavy cars. Many of you know them far better than I. Such an argument would resemble a plea to abolish prohibition before an audience of alcoholics.

The determination, in an objective way, of optimum maximum wheel loads is, however, a very crucial issue to the railroad industry today. The Board of Direction of AREA has indicated a measure of its interest in this subject by approving no less than five presentations relating to wheel loads this morning. The Research and Test Department of the AAR has similarly expressed its concern by programming for 1975 a cooperative investigation of the economics of wheel load which has been approved by the AAR's Committee on Research and by the Board of Directors of the AAR. Since this is the first of the five presentations you will hear today, and because it marks in a way the formal opening of the Research Department's cooperative inquiry, I think it appropriate to spend a few minutes reviewing for the record what has happened in the past 15 or 20 years with respect to the question of wheel load.

The arguments to increase wheel loads throughout the history of the railroad industry have been strong and effective. Grossly simplified, greater wheel loads brought about increased productivity. In the early days of technological development in the industry, the constraints on wheel loads were largely structural. Much of the technological advances made by the industry in its earlier days was brought about in order to cope with heavier wheel loads. These advances included strengthening bridges, increasing tie dimensions and reducing tie spacing, and increasing flexural strength of rail.

When the physical plant was sufficiently strengthened to permit them, higher

---

Note: Discussion open until October 15, 1975.

wheel loads permitted more carrying capacity per vehicle, lower investment per ton of capacity, and greatly increased flexibility and design, permitting higher net-to-tare ratios and reduced inspection and switching expense. The nominal capacities of mineral freight cars were increased first to 50 tons, then to 70, then 100 and lastly, in some cases, to 125 tons on 4 axles. While this was going on, there were those few who thought that there were economic arguments against cars of at least the last two designs. In 1957, C. J. Code of the Pennsylvania Railroad, who had previously established his reputation in the field of stress analysis and rail design, through his contributions to modern rail design with the 133, 155, and 140 lb rail sections, studies of corrosion fatigue, and upper fillet stresses, released the now famous report on Pennsylvania Railroad Test No. 591. This study had begun in 1951. In the test several 140 PS rails were drilled with a series of 5/64-inch-diameter by ¾-inch-deep holes in their heads perpendicular to head surface and at various locations in the vicinity of the gage corner. Brass pins were then driven into the holes and the rails were laid in No. 1 track at Bollivar curve, a 4-degree curve on the Pittsburgh Division. At the time, this track carried approximately 29 million gross tons annually. After some 75 million gross tons of accumulated traffic, the rails were removed from track, sectioned through the pins and photographed. The results were widely published and caused considerable consternation among railway engineers. I would like to quote the following conclusions from the report:

(1) On the high outer rail of curves there is a flow of metal at the top corner of the rail toward the gage side.

(2) This flow of metal extends to a depth of ¼ inch to ⅜ inch below the rail surface.

(3) The flow of metal toward the gage side extends back to the edge of the center arc and beyond probably to the center of the rail head.

(4) The magnitude of the deformation is positive evidence of shear stresses well beyond the yield point of steel.

There had been developing in this country during the 1950's a sense of security about rail. The cause of transverse fissures had been isolated, and the practice of control-cooling was developed to eliminate the offending hydrogen originated shatter-cracks. Rail produced after 1937 was free from this kind of failure. During the mid-1940's, the incidence of web failures, especially in 112-lb RE and 131-lb RE sections, had become alarming. Again the cause—high upper fillet curve stress, particularly under heavy locomotive wheel loads (there were no 100-ton or heavier cars in general use at this time)—was identified. The 115-lb RE and 132-lb RE sections developed by the AAR, and the 133-lb RE, 140-lb RE, and 155-lb PS rails developed by the Pennsylvania Railroad at Altoona eliminated the problem.

With transverse fissures and web failures apparently eliminated as problems in modern rail, it was generally held that the few remaining problems could be tolerated and all that was required was to retire rail of inadequate design. But hardly had this technological confidence been established when new concerns began to arise. Rail shelling, rail corrugations, head checks, and detailed fractures were all causing rail of even the so-called modern sections to be removed from track prematurely. All of these problems seemed to be, or to be related to, rail head surface defects. Shelling seemed to be the most insidious. Not only did the shells often break out, removing much rail steel, but often they would turn down from the original almost harmless horizontal orientation and form the nucleus of a potentially dangerous detail fracture. It was a concern over these conditions that led to the study of rail head plasticity using brass pins, and to renewed vigor in the study of the Joint Committee on Relation Between Track and Equipment of the Association of American Railroads. The Joint Committee worked closely with the Research Center (now Technical Center) of the AAR, and the University of Illinois.

The studies at the AAR Technical Center and the University of Illinois indicated that the cause of these surface-related rail defects was high shear stress under the surface of the rail, due to localized high contact pressures between wheels and rail. The contact pressures, of course, depended not only on wheel loads, but on wheel diameter as well. Relying heavily on analytical work published in 1930 by Thomas and Hoersch of the University of Illinois, entitled, "Stresses Due to the Pressure of One Elastic Solid Upon Another," and three-dimensional photoelastic work done by Dr. Frocht, the Joint Committee made the following recommendations regarding wheel diameter and maximum wheel load: For 33-inch wheels, maximum wheel load should be 26,400 lb or 800 lb per inch; for 36-inch wheels, 29,200 lb or 810 lb per inch; for 38-inch wheels, 31,200 lb or 820 lb per inch; 33,000 lb per wheel required 40-inch wheels, and 34,900 lb required 42-inch wheels.

These recommendations were made in April, 1959 to the AAR's Mechanical Division, but they were not accepted. Instead, the Mechanical Division agreed that cars built new on or after January 1, 1961, of over 70-ton nominal capacity, up to and including 100-ton nominal capacity, would be equipped with 36-inch-diameter wheels when 4-wheel trucks are used. To many this was considered grossly inadequate. At the 1960 annual meeting of the American Railway Engineering Association, C. J. Code presented an address entitled, "Wheel Load, Wheel Diameter, and Rail Damage" in which he attacked the Mechanical Division decision. In this paper, Code made the following observations and I quote, "Prior to 1945, three individuals to my knowledge made studies on the limitation of wheel load to limit damage using the Thomas and Hoersch report as the basis of their work. These were W. E. Robey on the Santa Fe, G. M. Magee, and myself. Each one of us separately came to the conclusion that to avoid all damage to the rail head from wheel loads, a limitation well below 800 lb per inch of diameter would be required; with a load on a 33-inch wheel not more than 24,000 lb and other diameters in proportion. I, for one, concluded, and I think the others reached similar conclusions, that such a limitation was not practical in view of the existence of several hundred thousand cars with 26,250 lb on a 33-inch-wheel." And lastly, Mr. Code said, "There is a current misconception that this proposal to limit wheel loads will cure our present problems of rail damage. Nothing could be further from the truth. Our present rail damage is resulting from wheels which are within this limitation. All that is hoped to accomplish by limiting wheel loads is to avoid the accumulation of a large number of cars with wheel loading in excess of that we now have, with resulting accelerated rail damage." In March a year later, G. M. Magee, then AAR's director of technical research, prepared an article entitled, "What Today's Heavier Wheel Loads Are Doing to Your Rails," which was published in *Railway Age*. Magee repeated many of Code's arguments, and went into the questions of effects of heavy loads on other maintenance-of-way expenses, such as tie renewal, surfacing, and lining, as well as rail renewal expense. Magee's approach, which combined theoretical analysis and pragmatic evidence, concluded that track maintenance expenditures for moving the same tonnage the same distance were dramatically increased when that transportation was affected in fewer but heavier cars. For example, he pointed out that track maintenance costs associated with 100-ton-capacity cars were 180% those of 50-ton cars.

To our knowledge, this marked the first attempt to quantify economically the results of a good deal of earlier purely technical investigation on the effects of heavy axle load on the true economics of transportation. As Magee and Code before him so aptly pointed out, the original work by Arthur Talbot did not apply to this problem. There is no way to increase rail size or track modulus to compensate for increased contact stress. In later years, Magee reversed his position at least to the point of agreeing that his arguments could be disputed on the evidence of one specific carrier, which did not appear to incur the higher transportation expense associated with larger cars. Similarly, Dr. Frocht's prediction of dire and immediate consequences from the use of heavy wheel loads, based solely on the only available, but yet inadequate theory, did not come to pass in terms either of severity or time span. Frocht's work was done solely in the elastic range. As Code pointed out, and Test 591 demonstrated, the high contact stresses which were causing the difficulties surely were in the plastic range.

Increasingly, evidence from many railroads indicate that while the penalties associated with the very heavy wheel loads may have been delayed, they are here at last. In 1965, I. A. Reiner, manager of engineering research for the Chessie System prepared a report entitled, "The Effects of 125-Ton-Capacity Four-Axle Cars on Track." By 1965, 100 tons on 4 axles had been accepted, and the push was on to increase this to 125 tons on 4 axles. Now even the flexural strength of rails would be tested. In fact, the first conclusion reached by Reiner was, "Some rails are not capable of supporting these cars under normal or any operating and maintenance condition." The recommendation was made that 125 tons on 4 axles be completely restricted from 90 lb or lighter rail. Reiner joined with Code in condemning the AAR's Mechanical Division for its overly liberal restrictions on wheel loads per inch of wheel diameter. "It should be mentioned that 100-ton-capacity cars have 960 lb per inch ratio instead of 810 lb per inch as recommended by the Joint Committee. While the AAR seems to be aiming for a load wheel rail diameter ratio of about 800 to 830 lb per inch, much foreign experience exists with a 550 to 650 lb per inch ratio, which in considering the difference in rail strengths and hardness is equivalent to U.S. 640 to 730 lb per inch ratio. The experience tends to support the view that a ratio of even 800 lb per inch is already too high for economic balance." Reiner pointed out that it was insufficient to consider only nominal or static loads: track irregularities and motion of equipment increased these loads, and the additional dynamic loads increased with speed. Reiner estimated the dynamic increase to be between 25 to 67 percent depending on speed and track condition. He estimated that the percentage increase for track maintenance expenditures is roughly 160% for traffic densities between 35 and 40 million gross tons and speeds of approximately 40 mph, for handling freight in 125-ton-capacity cars versus 50-ton-capacity cars, both on 4 axles.

More recent conclusions on this subject include those expressed by Professor Josef Eisenmann at a 1969 Railway Systems and Management Seminar in Chicago. Eisenmann, a consultant to German Federal Railways, agrees with many of his predecessors in laying the blame for rail shelling on excessive shear stress. He claimed, "We have found that shelling is caused by shear stresses, the shear stresses having maximum value at a depth of a quarter of an inch below the contact area. On the other side, we have to consider the strength of the steel. For a certain axle load, and a certain diameter of the wheel, the theoretical calculation gives answers about the strength of the steel of the rail. Our work shows that for an axle load of 25 long tons (27.5 kips), and a wheel diameter of 90 cm (36 inches), we need a steel with an ultimate tensile strength of 114,000 psi; for an axle load of 36 tons, a strength of 100 kg/mm^2 (142,000 psi.)."

Eisenmann's remarks concerning the ratio of wheel diameter to wheel load are reminiscent of the 1959 recommendation of the AAR Joint Committee on the effects of equipment on track. However, he brings a new variable into the problem—the strength of the steel used in the rail. The wheel diameter of 90 cm versus 25-long-ton axle loads translates to 380 lb per inch wheel diameter. But this recommendation is for a softer steel than commonly used in North America. The second recommendation converts to 550 lb per inch. This recommendation is for rail steel of 100 kg/mm^2 or 142,000 psi ultimate tensile strength, a steel somewhat stronger than standard carbon conventional North American rail steel which has an ultimate tensile strength of 136,000 psi.

Eisenmann's solution to rail shelling and its associated difficulties is to use better, stronger rail if nothing can be done to reduce the magnitude of wheel loads. Heat-treated steels exhibit an ultimate tensile strength of 175,000 psi. Using Eisenmann's previous recommendations, we can extrapolate to find wheel load to wheel diameter ratio for heat-treated rail following the German practice, presumably, a practice which does not damage rail at all from excess contact stress. Doing so reveals that heat-treated U. S. rail should tolerate wheel load to wheel diameter ratios of approximately 720 lb per inch diameter. This conclusion is supported by Code's statement that heat-treated rail is effective in retarding shell development. It must be pointed out, in this context, that Code's remarks were made in 1960 in a time when the heaviest loads were 70-ton-capacity cars on four 33-inch wheels, a ratio of about 800 lb per inch. Lastly, it should be emphasized, again, that the recommendation of the AAR's Joint Committee of about 800 lb per inch was not intended to eliminate rail shelling, merely to contain it at the levels being experienced in the years leading to the 1959 experimentation. Linear extrapolation indicates that to prevent surface damage to rail from cars of 263,000 lb gross weight on 4 axles requires steel with ultimate tensile strength of 200,00 psi. That would be a task to test the imagination of our metallurgists, and I rather suspect their solution would test our pocketbooks.

In relating the foregoing, my intention was not solely to refresh your memories but to point out, as well, why I believe previous efforts have not deterred the adoption of bigger and heavier cars. All of this work, as good as it was, and as convincing as these arguments appear to us, did little to convince the railroad managements who have purchased 350,000 4-axle cars of 263,000 lb gross weight in the past 15 years. More than 1,000,000 of the 1,700,000 cars in the fleet now exceed 70-ton capacity.

I believe there are three significant reasons for this. First, the nature of increased damage to track structure under heavy wheel loads is basically fatigue. Thus, the first or even the first several cars of this size contribute little, if any, to the deterioration of track. The arguments of the proponents of heavy cars gained credibility while those in opposition were diminished with each passage of the heavy equipment that did not bring disaster. The theory of fatigue teaches us that disaster only comes with the repeated loadings associated with a large number of vehicles operated over a long time span.

Secondly, and of equal importance, those who protested the heavier cars were considered negativists. They were not for something, they were against "progress," Regardless of the validity of their argument, human nature favors positive thinking and positive approaches.

Thirdly, and most important, we haven't done as good a job of translating accumulated traffic into dollar values of maintenance-of-way costs. The marketing and transportation people have been able to describe in a fairly precise way the dollar values of transportation savings attributable to big cars and the dollar values of business we can save or attract through their use. We engineers, on the other hand, have said merely that these cars will ruin our rail and track. Even when we show that cars in excess of 70 or 85 tons capacity do damage out of proportion to their increased capacity, we put our top management in the unfair position of balancing dollars against subjective speculation of increased costs.

It's a damned difficult job to associate direct or even relative costs with the passage of an individual wheel load, to do so with authority, and with supporting documentation that will stand the kind of scrutiny that such a declaration will be given. But it is a job we must do and do soon. It is a job the AAR project team I referred to earlier is prepared to tackle. This team is not made up of track engineers alone. Marketing, mechanical (they have increased costs too), rate makers, and transportation people will be represented as well. The wide spread of backgrounds and interests should, it is hoped, eliminate bias and add credibility to the project's findings.

One of the reasons I am hopeful that this project can meet some success is the availability now of computer-assisted engineering-economy analysis. Models can be created that will permit the cost of rail to be entered as a variable along with labor rates, car construction costs, and interest rates. These models will not only facilitate rapid calculation of a variety of sample cases, but they will permit us to test the sensitivity of the solutions to the various factors influencing the result. Therefore, it should be possible not only to make some rather good estimates of relative costs as a function of wheel load but to determine as well how sure we are of the results and to what degree they depend on factors subject to rapid or significant change.

Let me say that we must be prepared to discover that heavy cars are economically justified even when larger maintenance-of-way costs are included in the analysis. But such a determination would entail an accurate assessment of what those increased costs really are so that we could go to management with convincing reasons why maintenance-of-way budgets should benefit from the increased earnings of the cars in question.

By way of conclusion, let me say that our major competitor, the trucking industry, is not faced with the necessity of making similar studies because you, I, and the rest of the tax-paying public subsidize their maintenance-of-way expense. Many of us agonized at Christmas time last year while Congress increased maximum permissible truck weights. The point was not only that by so doing Congress improved the competitive position of our competitors, it was also that by so doing Congress further disrupted the laws of the free market place. The trucking industry and governmental bodies are not held financially responsible for their wheel load decisions in the way we are. I believe strongly that questions as important as these to the Nation's economics are not best determined by politics or by regulation by those with no financial responsibility for their decisions. The laws of economics and the free market place are better ways to resolve such questions. Such a process would not be applied were our railroads or their roadbeds to be nationalized. To achieve economically realistic answers to questions of optimum wheel load, the decision is best made by those financially responsible for both the track and the transportation conducted over it.

Heavy Four-Axle Cars and Their Maintenance of Way Costs

76–653–15

By ROBERT E. AHLF
Manager, Systems Planning-Operations
Illinois Central Gulf Railroad

In allocating scarce maintenance-of-way dollars to our different lines and in developing costs for pricing, it is generally recognized that maintenance-of-way-and-structures costs vary to a large extent with the tonnage carried. The extent of cost variability with tonnage has been argued, researched, and debated countless times with widely varying findings and opinions. My purpose is not to get into that argument, which I believe rests with the long-run vs. short-run perspective of one's costing viewpoint.

On the ICG we consider that roughly 53% of our total MW&S expense and capital investment is incremental; that is, it varies with tonnage moving over the railroad. We are endeavoring to answer two questions: One is how that 53% portion of MW&S cost varies with car capacity. The other is how the kind and condition of track structure affects its cost of maintenance.

Like most complex problems, it is mind-boggling unless we break it down into smaller components. Different portions of that 53% vary differently with car size. This is because different cost elements of the track structure behave differently under the loads imposed by traffic. The approach taken in this study has been to categorize these different portions of that 53% into groups such that all (or most) elements of each respective group behave similarly under increased car weights. To appropriately break down the MW&S cost items into these groups, we used our Responsibility Accounting costs which are broken down to more specific categories than are the Accounts in Rail Form A. The four basic groups of MW&S variable cost are summarized as follows:

1. MW&S costs per ton-mile that vary with rail deflection (the amount of vertical motion of the rails as trains pass over them). These are the costs associated with subgrade stability, ballast, ties, track inspection, lining, and surfacing. These constitute 36.3% of our variable MW&S costs on the ICG.
2. MW&S costs per ton-mile that vary with bending stress in rail (the flexural stresses inside the rails resulting from the bending of the rails as trains pass over them). These are costs associated with bolt tightening, turnout renewal, derailment repairs, wreck clearing, joint renewal, and miscellaneous track fittings. These constitute 12.5% of our variable MW&S costs on the ICG.
3. MW&S costs per ton-mile that vary with contact pressure on rail. These are costs associated with the life of the rail, which with heavy cars, is directly limited by rail head contact phenomena, primarily shearing stresses. These are costs associated with rail life, rail welding, rail renewal, etc. These constitute 11.1% of our variable MW&S costs on the ICG.

Note: Discussion open until October 15, 1975.

4. MW&S costs per ton-mile that vary in direct relation to the average of the above three groups. These are costs associated with tools, machinery, supervision, clerical, and miscellaneous labor-related expenses. These constitute 40.1% of our variable MW&S costs on the ICG.

Following this, we have used data from past research as well as recent field measurements to develop the relationship between car size and rail deflection, rail stress, and rail contact pressure. For the first two items (rail deflection and rail stress) we used the work of Professor Talbot of the University of Illinois. Even with all the recent emphasis on train-track dynamics, probably the simplest, most correct, and most generally applicable work on this subject of track structure and track reaction under traffic is the set of relationships developed in 1913 by Professor Talbot and his joint committee under the auspices of the AREA, ASCE, and ARA (now AAR).

Professor Talbot's approach was based on the treatment of track as a continuous beam on an elastic foundation, derived from a combination of field testing and theoretical derivations. The relationships he developed are as valid today as they were in 1913. The effects of axle loading and wheel spacing were treated as independent variables which can be changed to correspond to any type of car or locomotive. The same is true of rail size, and rail support.

Through his field measurements and his calculations, Dr. Talbot developed an index of the firmness of rail support (ties, ballast, subgrade). It is referred to as *U*, the modulus of elasticity of rail support. *U* is defined as the load per inch of rail to depress the rail one inch, usually expressed in pounds per inch per inch. *U* is not related to rail stiffness or size; it is related only to the stiffness of the track structure below the rail. Fig. 1 illustrates several representative *U* values. The important thing to note is that the higher the *U* value, the firmer the rail support. Recently, we have measured rail deflections out on the railway, under track conditions ranging from very poor to very good. The *U* values on Fig. 1 are representative of our findings in the field.

To compute rail deflection and rail stress under different car sizes, we used several factors and combinations of factors. Three rail sizes of common usage (90, 115, and 132 lb) were combined with the five cases of *U* values, giving 15 different track cross sections for comparative analysis, ranging from very poor ($U=1000$, rail weight$=90$) to very good ($U=5000$, rail weight$=132$).

The analysis superimposes the effects of adjoining wheels spaced 70 inches in the trucks, and spaced 80½ inches apart in adjoining cars. The two equations used, one for rail deflection, the other for rail bending, are shown in Fig. 2.

We then evaluated different wheel loads (representing different nominal car sizes), all with an impact factor of 35% for 40 mph speeds, as developed by the AREA. Nominal car capacities of 50 tons, 83 tons, 100 tons, and 125 tons were evaluated. The results of these evaluations are shown on Figs. 3 and 4 for rail deflections, and for rail bending stresses, respectively.

It is concluded from Fig. 3 that a 1% increase in car capacity results in an 0.73% increase in the 36.3% of variable cost per gross ton-mile that is regarded as varying with rail deflection.

It is concluded from Fig. 4 that a 1% increase in car capacity results in an 0.70% increase in the 12.5% of variable cost per ton-mile that is regarded as varying with rail stress in bending. The solid horizontal line across Fig. 4 is the maximum allowable bending stress with appropriate safety factors, applicable to track which behaves in a manner similar to the continuous beam on an elastic foundation. This is based on a safety factor of 25% for abnormal track conditions. When measuring rail deflections under traffic, and on different kinds of track, we found this 25% safety factor to be quite sufficient for jointed rail in average or better track (U values of 3000 or greater). Where the U values were 3000 or greater we found the rail deflections at joints to be less than 25% higher than rail deflections at rail midspans.

However, we found that under poor track conditions ($U = 2000$ or less), the rail support is so unstable that joint deflection is often 400% of midspan rail deflection. In other words, the assumption of a continuous beam on an elastic foundation does not hold true under rail joints and other discontinuities in poor track. It appears that the relatively weak rail support is unable to withstand the impact of traffic over joints (the weakest part of the rail). This weakness rapidly progresses to a larger amount of joint deflection, which accelerates the loosening of bolts, the wear of joints and fishing surfaces, and ultimately cold bends the rails and joint bars. Thus, we have concluded that living with this joint instability, or overcoming it from time to time, will cost far more than would be indicated by treating the structure as a continuous beam on an elastic foundation. The cost aspects of this problem will be discussed and quantified later.

Under such conditions of joint instability ($U = 2000$ or less) the rail ends behave more like independent cantilevers than a continuous beam—at least with regard to vertical motion. If we assume the tie nearest the joint provides little support (which generally applies unless the track has been recently tamped), then the bending moment is approximately twice the bending moment of a continuous beam on an elastic foundation. On this basis, we have concluded that for track having a U value of 2000 or less, the factor of safety for abnormal track conditions should be doubled from 25% to 50%. This is shown on Fig. 4 as the limiting factor for considering rail bending stresses when the U value is 2000 or less.

Stresses above these horizontal lines (the solid line when $U = 3000$ or higher or the dashed line when $U = 2000$ or lower) will permanently bend the rail and ultimately break it.

The third group of variable MW&S costs are those that vary with rail contact pressure. For this group of costs we have relied on the work of others, primarily Frocht, Reiner, Code, Magee, and Hay, as well as numerous observations being currently conducted by others concerned with this problem. By now, a number of mineral hauling roads have been living with heavy cars for some time. The heavy cars are reducing rail life by creating metal flow and shelling resulting from high shearing stresses, fatigue, and other phenomena in the top of the rail head. This has little relationship to rail size or track structure; it is largely related to the contact stresses at the point of wheel-rail contact. That point of wheel-rail contact occupies an area of only 1/5 to ⅜ square inch. Increased axle loadings on relatively small wheels (36 inches generally) have increased the pressure brought to bear on the 1/5 to ⅜ square inch of contact area to the extent that shearing stresses are causing rail head surfaces to shell or spall off, dramatically reducing the rail life. A lot remains to be known about this problem, and research is continuing. For these reasons, we have prepared Fig. 5 at the risk of over-simplifying a wide variation of data. Contrary to some of the earlier research work on this subject, the rail life curve as a function of car size does not appear to take the form of a neat hyperbola. Rather the curve is somewhat flat through the range of small and intermediate size cars, dropping abruptly and with considerable spread in the range of 90–110 ton cars. The broad band assumed by the curve in Fig. 5 reflects the great variance and disparity among the numerous tests and observations. A number of complex, interrelated factors are at work here, and considerable work remains before the broad curve can be more precisely defined. Nevertheless, the information we have found to date, as noted in Fig. 5, is indicative of a sharp drop in rail life when we get into the heavier car sizes.

Fig. 6 illustrates the long-run relationship of rail cost vs. car size. It is simply the inverse of the middle of the curve on Fig. 5. Note the curved relationship shown. Thus a 1% increase in car capacity causes an increase in rail life costs of between 0.2% and 5.0%. That applies to 11.1% of our variable MW&S cost.

This leaves the fourth group of variable MW&S costs which we assume varies about as the average of the above three categories, or 0.5% to 1.5% per 1% increase in car capacity.

These four groups of costs are summarized on Fig. 7. Because of the similar behavior of increases in rail bending stress and rail deflection, the costs associated with these two functions have been grouped as one. The most important part of Fig. 7 is the bottom row which summarizes how the variable portion of our MW&S cost varies with car capacity increases.

Because the relationships developed up to this point have utilized the costs of our entire system of lines on the ICG, they are most representative of average track conditions. Later, we will discuss how they can be varied for poor track and for better-than-average track. But at this point we will apply the table on Fig. 7 to a costing problem on average track (shown on Case 3 on Fig. 1). This track would have a U value of 3000 lb/in, and a rail weight of 115 lb/yd. At this point, some mention should be made of average track. What is average track? In this context, what we are looking for is not average track, but rather the kind of track that carries the average ton-mile of railway traffic. Because something like 90% of our traffic moves over 10% of our track, average track for this purpose would be pretty good. This is why we assumed Case 3 on Fig. 1 to be average track, $U = 3000$ and weight = 115. Refer to Fig. 8 for the application of these data to the costing problem on average track.

The behavior of rail deflection (and logically the costs that vary with it) is shown for average track on Fig. 3. Good track (down at the bottom of the figure) has roughly 75% of the deflection of average track. Poor track (up at the top of the figure) is indicated to have 140% of the deflection of average track. These relationships are based upon the continuous beam on an elastic foundation concept, which as mentioned earlier, does not hold true for poor track because of joint instability.

Similarly, from Fig. 4, it can be seen that the rail bending stresses for good track will approximate 90% of those for average track; and that rail-bending stresses for poor track are indicated to approximate 110% of those of average track. Again, this does not fully assess the situation for poor track because of the effect of low U values on joints.

Fig. 9 expands upon these various factors to derive the relationships that are necessary for preparing a set of cost curves for poor and for good track. On Fig. 9 is shown the 140% relationship for the poor track deflection-related costs as derived from the continuous beam concept. Added to this is an adjustment factor for the effect of weak joint support. This weak joint adjustment is based on the fact that roughly 18% of the ties, ballast, and associated items are affected by the much greater deflection at the joints, found to be 400% of the deflection at the rail's midspans.

Fig. 9 also includes an adjustment for the effect upon poor track of the increased rail bending stresses resulting from the weak joint support. As explained earlier, this increase in rail bending moment, and stress, is roughly 200% of that which occurs at the midspan of the rails. Because this increase in stresses near the joints has the effect of reducing the life of the rails, as well as that of the joint bars and fittings, 100% of the costs associated with rail stresses in bending are regarded as being affected.

Fig. 9 is developed to indicate not only the variable costs of poor and good track, but also indicates the portion of cost associated with the four major cost categories. Note that in the case of poor track, a relatively high percentage of cost is associated with deflection and bending stresses; and that a lower percentage of the cost of good track is associated with these items. The opposite holds true for the portion of cost associated with contact stresses; relatively low for poor track and relatively high for good track. What this means, in quantified terms, is simply that in the case of poor track a higher percentage of the total cost is expended in spot tamping, bolt tightening, and changing out broken joints and rails as a result of weak joint support. Tie life is also greatly reduced under such joints.

Tables summarizing these effects for poor and good track are shown as Figs. 10 and 11. The costs of the major components of MW&S variable cost have been adjusted to correspond to the characteristics of both poor track and good track in accord with the relative proportions computed on Fig. 9.

References to Figs. 10 and 11 might cause one to wonder why the bottom line of Fig. 11 for good track is higher than for that of Fig. 10 for poor track. These are not cost ratios; they are rates of change. The bottom lines of Figs. 10 and 11 simply quantify the fact that poor track MW&S costs change at a lower ratio than do MW&S costs for good track.

Curves summarizing these effects for poor and good track as well as for average track are shown on Fig. 12, plotted for a railway having 53% average MW&S costs regarded as variable, and amounting to 76 cents per thousand gross-ton-miles, and whose average carload is 54 tons.

Fig. 12 illustrates a number of things. One is that a sizeable cost increase in MW&S is associated with increased car weights. Secondly, it illustrates what every maintenance officer knows that it costs less under similar conditions to maintain good track than to maintain poor track, once the track has been brought up to good condition. Furthermore, these curves quantify the difference in maintenance costs for good, average, and poor track. This is very useful information not only for rational pricing, but for the evaluation of the benefits of upgrading track. On the ICC, we figure that it costs about $70,000 to $100,000 per mile to take a piece of bad track and put it in good shape, including relay of rail.

CONCLUSIONS

One should not conclude that MW&S costs as a function of track structure and car size can be neatly summed up and plotted on a series of curves to be applied as inviolate pillars of truth. Any experienced maintenance of way officer will list a number of other variables that affect his costs. Among these are type of subgrade soil, climate, curvature, gradient, operating speed, relative dispersion vs. concentration of heavy and light cars, road crossings, turnouts, welded vs. jointed rail, and a myriad of other elements. However, we can assume that these other variables are generally too obscure to quantify and that it would be useful to have a basic set of tables and curves which accept these other variables at face value, assuming they must be considered as local variations. Figs. 7, 9, 10, 11, and especially Fig. 12 serve this purpose.

Because different railways have different characteristics and/or costing philosophies, it is useful to illustrate how Fig. 12 can be adjusted for an example where average variable MW&S cost is 50 cents/1000 GTM with average carloads of 60 tons.

We would simply set the 50-cent point on the ordinate for 60-ton cars as the point needed to set the position of the average track curve. This curve can then be plotted by the same method illustrated on Fig. 8.

For poor track, we would set the ordinate for 60-ton cars at 190% of the ordinate for average track, or $(1.90 \times 50) = 95$ cents. We set 95 cents as the ordinate for 60-ton cars, and plot the curve for poor track based on the table on Fig. 10.

For good track, we would set the ordinate for 60-ton cars at 81% of the ordinate for average track, or $(0.81 \times 50) = 40.5$ cents. We set 40.5 cents as the ordinate for 60-ton cars, and plot the curve for good track based on the table on Fig. 11.

Fig. 12 does not attempt to illustrate the cut-off points at which cars of certain sizes are hazardous. Fig. 5 gives a good indication of the effect of car size and rail life. One can't escape the conclusion (as substantiated by testing and experience) that heavy cars are accelerating the incidence of rail defects.

Fig. 4 gives an indication of the effect of heavy cars and poor track on overstressing the rails in bending. From this it can be reasonably concluded that 125-ton cars should not be allowed on 90-lb rail.

These relationships provide useful information for establishing MW&S policy on certain matters. For example, to accommodate 100-ton cars, the track should have either a U value of 3000 with 90-lb rail, or a U value of 2000 with 115-lb rail. This is a rather common dilemma faced by railways trying to upgrade lines. Should we concentrate first on drainage, ballast, and ties, or should we lay heavier rail? From a rail stress standpoint it makes scarcely a difference. Refer to Fig. 3. Given a U value of 2000 with 90-lb rail to start with, we can reduce rail deflection and related costs by 50% simply by improving drainage, ballast, and ties to increase the U value to 4000. The other alternative of retaining the poorer substructures and laying heavier rail has a negligible effect on these costs.

Also, it costs roughly twice as much to relay rail as to perform a good job of drainage, ballasting, and timbering. The conclusion from this is that the first priority for maximum cost-effectiveness in upgrading track is to improve the U value; that is, concentrate on drainage, ballast, and ties. It will be significantly more effective and less expensive than relaying the rail with a heavier section.

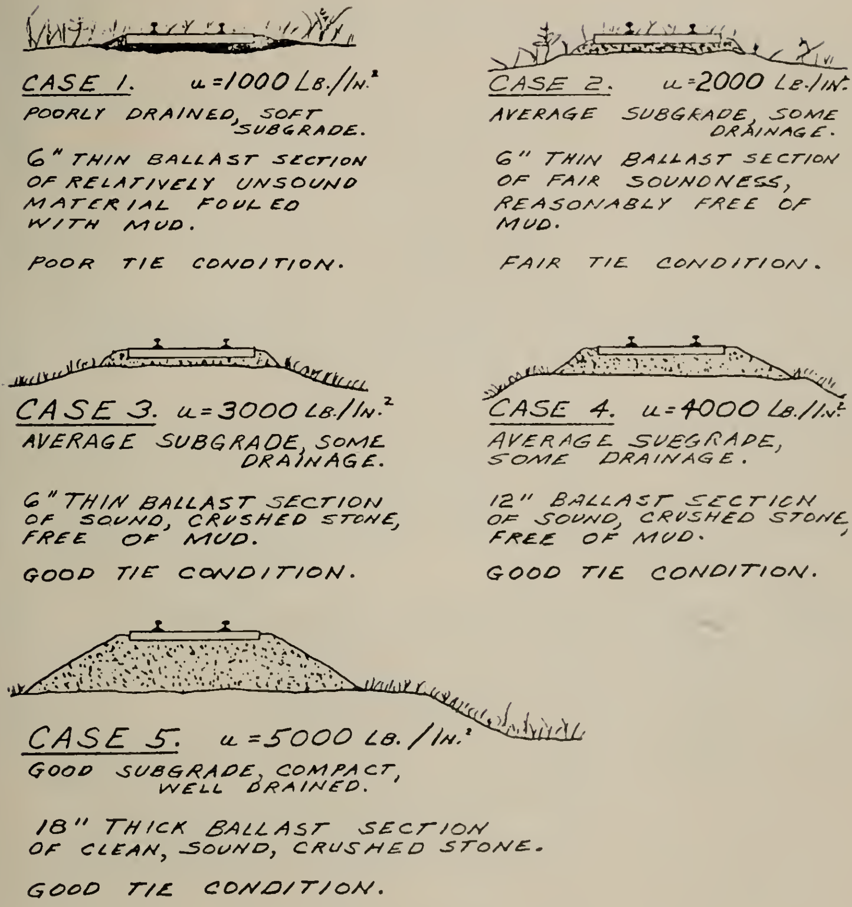
To summarize these conclusions:

1. Rational policy should include the MW&S cost relationships as noted on Figs. 7, 8, 9, 10, 11, and exemplified on Fig. 12.
2. 125-ton cars should not be allowed on 90-lb or lighter rail.
3. 100-ton cars should be restricted to 90-lb rail having a minimum U value of 3000, or to 115 lb rail having a minimum U value of 2000.
4. It is much more effective and less costly to upgrade 90-lb track by increasing the U value than to relay with heavier rail.
5. Good track is far less expensive to maintain than poor track, and the spread increases with car size, as quantified on Fig. 12.

EFFECT ON STEEL BRIDGES

At this point, I would like to include some data on the effect of car weights on steel bridges as furnished by Bill Byers, bridge engineer, Western Lines, Santa Fe, and chairman of AREA Committee 16—Economics of Plant, Equipment and Operations. Bill points out that the effect of increasing the weight of cars on short-span steel bridges or on truss members such as floorbeams or floorbeam hangers where the load on a short span is critical is shown on Fig. 13. Points below the curve labeled "fatigue strength" represent safe combinations of stress and number of cycles. Points above the curve represent unsafe combinations. The stress levels shown on the diagram represent values that could reasonably be expected to occur at stress raisers produced by poor details, poor construction practices or accidental damage when the computed stress in a member is near the maximum stress allowed by AREA rating rules. It can be seen that one-hundred-million net revenue tons carried in 50-ton cars would not be critical under the assumed conditions but that one-hundred-million net revenue tons could not be safely carried in 100-ton cars. For conditions assumed, failure could be expected after approximately four-hundred million net revenue tons in 50-ton cars or approximately thirty-three-million net revenue tons in 100-ton cars had been carried by the member.

The following assumptions were made in developing the diagram: The tonnage was assumed to be handled in 100-car trains with four-unit locomotives. This probably understates the power requirements for the trains with 100-ton cars relative to the trains with 50-ton cars but this effect is of relatively minor importance. A rating stress of 21,000 psi was assumed. This would be appropriate for either Bessemer steel floorbeams or for riveted floorbeam hangers made from A 7 steel with a yield point of 35,000 psi, which is a fairly typical value. (See Chapter 15, Section 7.3.4.3 of the AREA Manual). A stress concentration factor of 1.5 was assumed. The effect of differences in axle spacing between locomotives and cars was not considered which would allow somewhat heavier axle loadings on the locomotive to equal the stress levels produced by the 100-ton cars. The values given are for purposes of illustration only and should not be used as a basis for evaluating the strength of a questionable structure. The more likely causes of significant stress raisers include sharp re-entrant corners, heavy drifting of rivet holes during erection, cracks initiated by loads not considered in the design of the member, such as loads perpendicular to the web of a beam introduced by bracing systems or transverse bending of beam webs caused by loading one edge of the flange, accidental damage and undercut or other weld defects. The effects discussed are most significant for members that are completely unloaded between the passage of the first and second truck of a car but are important for floorbeams or floorbeam hangers supporting stringers with spans up to about 25 ft in length.



CASE 1. u = 1000 LB./IN.²

POORLY DRAINED, SOFT SUBGRADE.

6" THIN BALLAST SECTION OF RELATIVELY UNSOUND MATERIAL FOULED WITH MUD.

POOR TIE CONDITION.

CASE 2. u = 2000 LB./IN.²

AVERAGE SUBGRADE, SOME DRAINAGE.

6" THIN BALLAST SECTION OF FAIR SOUNDNESS, REASONABLY FREE OF MUD.

FAIR TIE CONDITION.

CASE 3. u = 3000 LB./IN.²

AVERAGE SUBGRADE, SOME DRAINAGE.

6" THIN BALLAST SECTION OF SOUND, CRUSHED STONE, FREE OF MUD.

GOOD TIE CONDITION.

CASE 4. u = 4000 LB./IN.²

AVERAGE SUBGRADE, SOME DRAINAGE.

12" BALLAST SECTION OF SOUND, CRUSHED STONE, FREE OF MUD.

GOOD TIE CONDITION.

CASE 5. u = 5000 LB./IN.²

GOOD SUBGRADE, COMPACT, WELL DRAINED.

18" THICK BALLAST SECTION OF CLEAN, SOUND, CRUSHED STONE.

GOOD TIE CONDITION.

Fig. 1

RAIL DEFLCTION EQUATION:

$$Y_M = 0.94 \frac{P}{u} \sqrt[4]{\frac{u}{4EI}}$$

Y_M = RAIL DEFLECTION, INCHES.

P = DYNAMIC WHEEL LOAD, LBS.

u = MODULUS OF ELASTICITY OF RAIL SUPPORT, LBS./IN.^{2}
E = MODULUS OF ELASTICITY OF RAIL STEEL, LBS./IN.^{2}
I = MOMENT OF INERTIA OF RAIL, IN.^{4}

THIS EQUATION INCLUDES SAFETY FACTORS OF:
5% FOR LOAD VARIATION.
15% FOR UNBALANCED SUPERELEV.
25% FOR ABNORMAL TRACK CONDITION.

RAIL BENDING STRESS EQUATION:

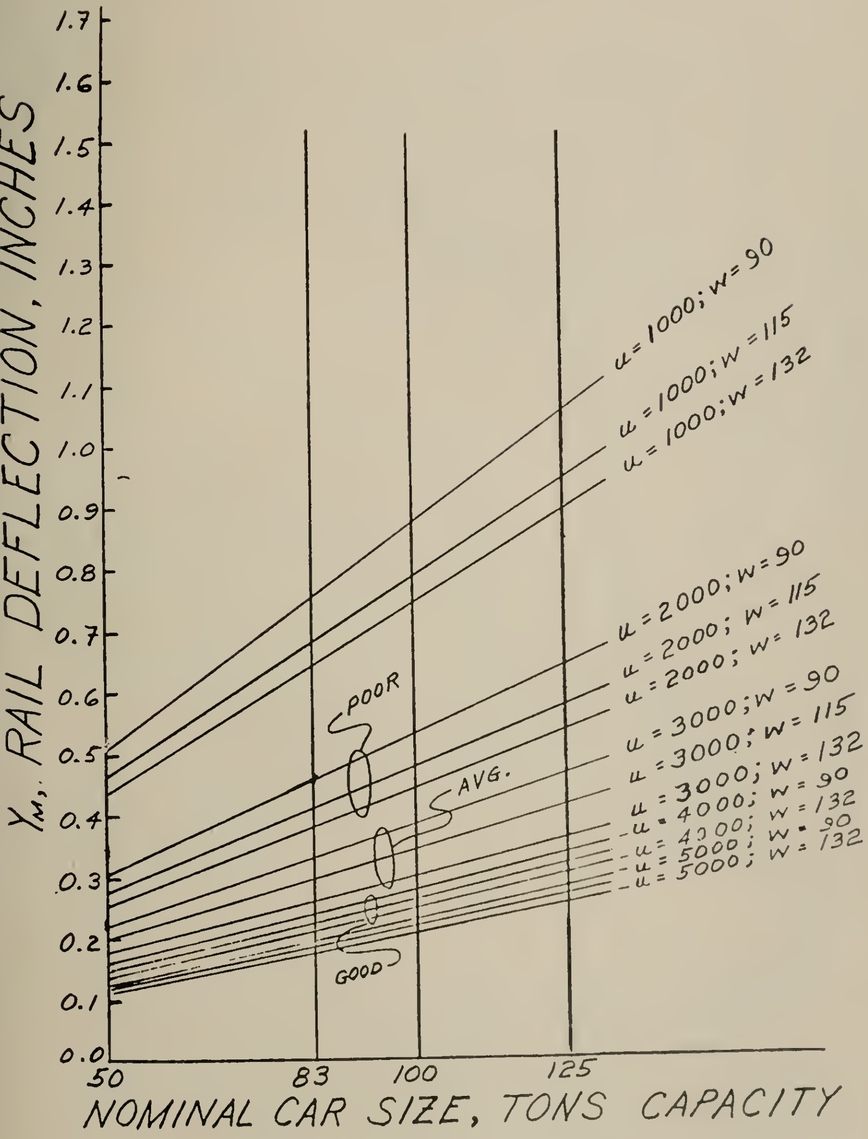
$$f_M = 0.207 \frac{Pc}{I} \sqrt[4]{\frac{4EI}{u}}$$

f_M = RAIL STRESS, LBS./IN.^{2}

c = DISTANCE TO RAIL'S NEUTRAL AXIS, INCHES.

OTHER SYMBOLS SAME AS ABOVE.

Fig. 2



Y_M, RAIL DEFLECTION, INCHES
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
50
83
100
125
NOMINAL CAR SIZE, TONS CAPACITY
u = 1000; w = 90
u = 1000; w = 115
u = 1000; w = 132
u = 2000; w = 90
u = 2000; w = 115
u = 2000; w = 132
u = 3000; w = 90
u = 3000; w = 115
u = 3000; w = 132
u = 4000; w = 90
u = 4000; w = 132
u = 5000; w = 90
u = 5000; w = 132
POOR
AVG.
GOOD

Fig. 3

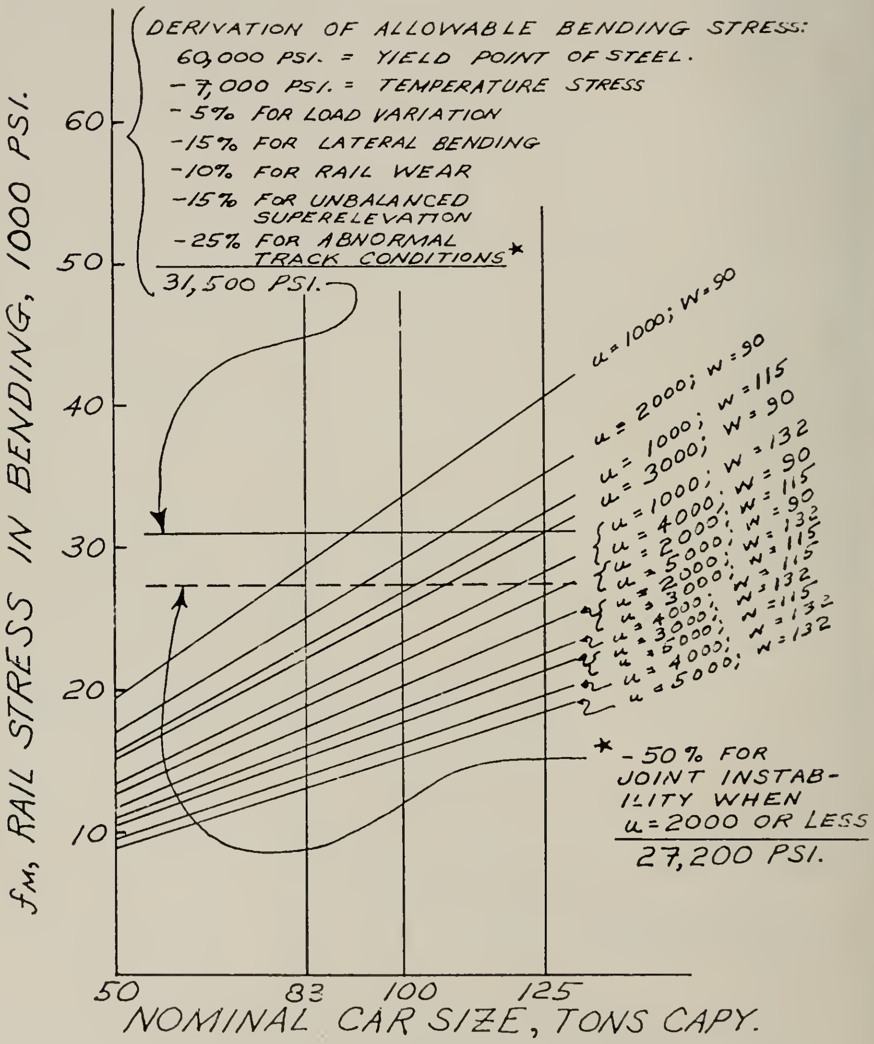

DERIVATION OF ALLOWABLE BENDING STRESS:
60,000 PSI. = YIELD POINT OF STEEL.
− 7,000 PSI. = TEMPERATURE STRESS
− 5% FOR LOAD VARIATION
− 15% FOR LATERAL BENDING
− 10% FOR RAIL WEAR
− 15% FOR UNBALANCED SUPERELEVATION
− 25% FOR ABNORMAL TRACK CONDITIONS*
31,500 PSI.
u = 1000; W = 90
u = 2000; W = 90
u = 1000; W = 115
u = 3000; W = 90
u = 1000; W = 132
u = 4000; W = 90
u = 2000; W = 115
u = 5000; W = 90
u = 2000; W = 132
u = 3000; W = 115
u = 4000; W = 115
u = 3000; W = 132
u = 5000; W = 115
u = 4000; W = 132
u = 5000; W = 132
* − 50% FOR JOINT INSTABILITY WHEN u = 2000 OR LESS
27,200 PSI.
fM, RAIL STRESS IN BENDING, 1000 PSI.
60
50
40
30
20
10
50
83
100
125
NOMINAL CAR SIZE, TONS CAPY.

Fig. 4

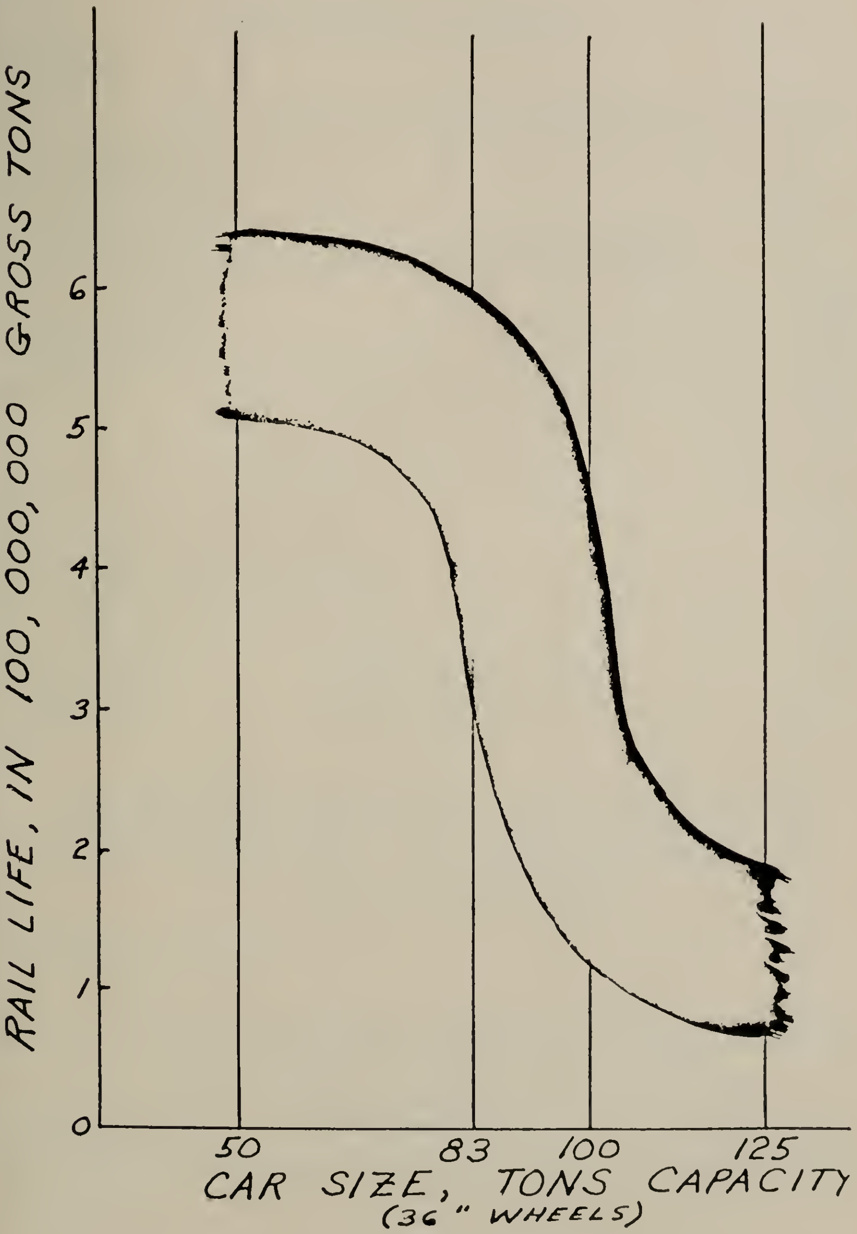

RAIL LIFE, IN 100,000,000 GROSS TONS
0
1
2
3
4
5
6
50
83
100
125
CAR SIZE, TONS CAPACITY
(36" WHEELS)

Fig. 5

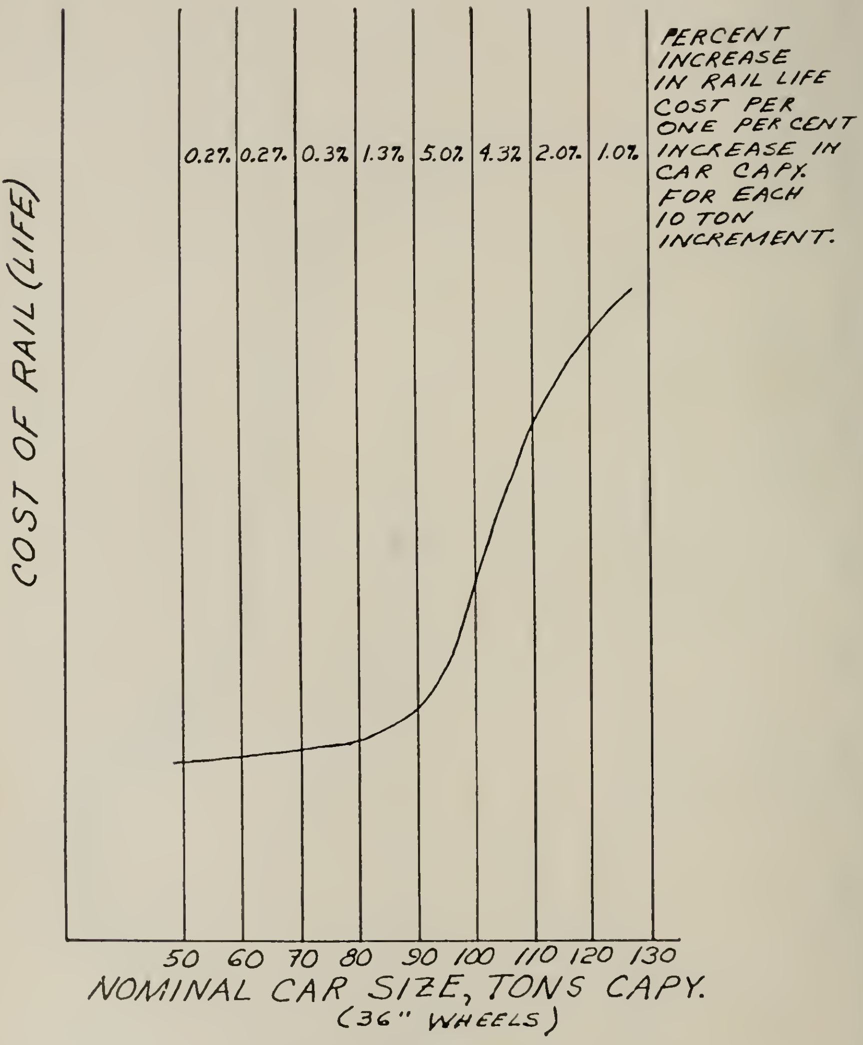
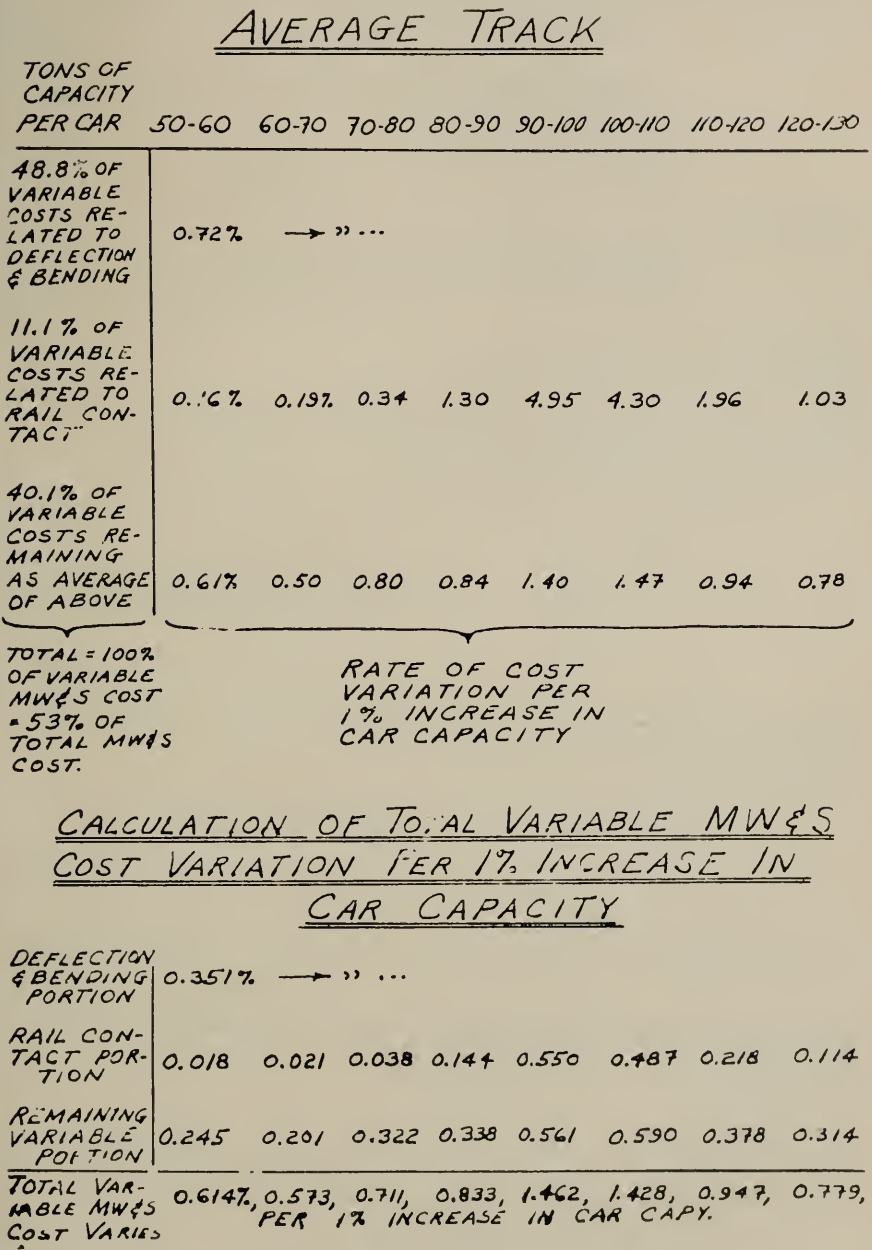

PERCENT INCREASE IN RAIL LIFE COST PER ONE PER CENT INCREASE IN CAR CAPY. FOR EACH 10 TON INCREMENT.
0.2%
0.2%
0.3%
1.3%
5.0%
4.3%
2.0%
1.0%
COST OF RAIL (LIFE)
50
60
70
80
90
100
110
120
130
NOMINAL CAR SIZE, TONS CAPY.
(36" WHEELS)

Fig. 6



AVERAGE TRACK

TONS OF CAPACITY PER CAR	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130
48.8% OF VARIABLE COSTS RELATED TO DEFLECTION & BENDING	0.72%	→ ” ...						
11.1% OF VARIABLE COSTS RELATED TO RAIL CONTACT	0.16%	0.19%	0.34	1.30	4.95	4.30	1.96	1.03
40.1% OF VARIABLE COSTS REMAINING AS AVERAGE OF ABOVE	0.61%	0.50	0.80	0.84	1.40	1.47	0.94	0.78

TOTAL = 100% OF VARIABLE MW&S COST = 53% OF TOTAL MW&S COST.

RATE OF COST VARIATION PER 1% INCREASE IN CAR CAPACITY

CALCULATION OF TOTAL VARIABLE MW&S COST VARIATION PER 1% INCREASE IN CAR CAPACITY

DEFLECTION & BENDING PORTION	0.351%	→ ” ...						
RAIL CONTACT PORTION	0.018	0.021	0.038	0.144	0.550	0.487	0.218	0.114
REMAINING VARIABLE PORTION	0.245	0.201	0.322	0.338	0.561	0.590	0.378	0.314
TOTAL VARIABLE MW&S COST VARIES	0.614%,	0.573,	0.711,	0.833,	1.462,	1.428,	0.947,	0.779,

PER 1% INCREASE IN CAR CAPY.

Fig. 7

EXAMPLE OF APPLICATION OF MW&S COSTING BASED ON TWO CAR SIZES

CONDITIONS: Average track: U = 3000, w = 115.

Variable portion of MW&S cost for this road is 76¢ per 1000 gross ton miles and comprises 53% of total MW&S cost.

Average size of load is presently 54 tons.

PROBLEM: What is cost of MW&S to move coal in 83 ton cars (220,000 lb. gross) vs. 100 ton cars (263,000 lb. gross), with a 100% empty return.

Begin with present conditions -- Variable cost is now 76¢/1000 g.t.m. for 54 ton cars.

Refer to last row, first column of Figure 7. Increasing the car size from 54 to 60 tons, causes an 0.614% variation in cost per 1% variation in car size.

$$\frac{60T - 54t}{54t} = \frac{6}{54} = 11.1\% \text{ increase in car size.}$$

$$(11.1\%)\ \frac{(0.614\%)}{(1.00\%)} = 6.82\% \text{ increase in variable cost.}$$

(76¢/1000 g.t.m.) (106.82%) = 82¢/1000 g.t.m. in 60t cars.

Refer to last row, second column of Figure 7. Increasing the car size from 60 to 70 tons, causes an 0.573% variation in cost per 1% variation in car size.

$$\frac{70t - 60t}{60t} = \frac{10}{60} = 16.6\% \text{ increase in car size.}$$

$$(16.6\%)\ \frac{(0.573\%)}{(1.00\%)} = 9.50\% \text{ increase in variable cost.}$$

(82¢/1000 g.t.m.) (109.50%) = 90¢/1000 g.t.m. in 70t cars.

Refer to last row, third column of Figure 7. Increasing the car size from 70 to 80 tons, causes an 0.711% variation in cost per 1% variation in car size.

$$\frac{80t - 70t}{70t} = \frac{10}{70} = 14.3\% \text{ increase in car size.}$$

$$(14.3\%)\ \frac{(0.711\%)}{(1.00\%)} = 10.2\% \text{ increase in variable cost.}$$

(90¢/1000 g.t.m.) (110.2%) = 99¢/1000 g.t.m. in 80t cars.

Fig. 8

Refer to last row, fourth column of Figure 7. Increasing the car size from 80 to 83 tons, causes an 0.833% variation in cost per 1% variation in car size.

$$\frac{83t - 80t}{80t} = \frac{3}{80} = 3.75\% \text{ increase in car size.}$$

$$(3.75\%)\ \frac{(0.833\%)}{(1.00\%)} = 3.12\% \text{ increase in variable cost.}$$

(99¢/1000 g.t.m.) (103.12%) = 102¢/1000 g.t.m. in 83t cars.

Again refer to last row, fourth column of Figure 7. Increasing the car size from 80 to 90 tons, causes an 0.833% variation in cost per 1% variation in car size.

$$\frac{90t - 80t}{80t} = \frac{10}{80} = 12.5\% \text{ increase in car size.}$$

$$(12.5\%)\ \frac{(0.833\%)}{(1.00\%)} = 10.4\% \text{ increase in variable cost.}$$

(99¢/1000 g.t.m.) (110.4%) = 109¢/1000 g.t.m. in 90t cars.

Refer to last row, fifth column of Figure 7. Increasing the car size from 90 to 100 tons, causes a 1.462% variation in cost per 1% variation in car size.

$$\frac{100t - 90t}{90t} = \frac{10}{90} = 11.5\% \text{ increase in car size.}$$

$$(11.5\%)\ \frac{(1.462\%)}{(1.00\%)} = 16.8\% \text{ increase in variable cost.}$$

(109¢/1000 g.t.m.) (116.8%) = 128¢/1000 g.t.m. in 100t cars.

SUMMARY

ITEM	83t cars	100t cars
Variable MW&S cost in terms of gross car weight	102¢/1000 gtm	128¢/1000 gtm
Net to gross tonnage ratio for round trip cycle	110t /load 27t /empty = 137gt /83 nt	131.5t /load 31.5t /empty = 163 gt /100 nt
Variable MW&S cost in terms of net lading weight	$\frac{(102¢)}{(1000)}\ \frac{(137)}{(83)}$ = 168¢ /1000 ntm	$\frac{(128¢)}{(1000)}\ \frac{(163)}{(100)}$ = 209¢ / 1000 ntm

Fig. 8 (cont'd)

COMPUTATION OF POOR AND GOOD TRACK COSTS DERIVED FROM AVERAGE TRACK COSTS @ 54 TONS PER LOAD

Average Track (converted to basis of 100% =$100 for simplicity)	Poor Track	Good Track
36.3% Deflection related costs $36.30	Up to 140% =$51.00. Adjustment for joint effect = 18% of $51.00 @ 400% added to 82% of $51.00 @ 100% = $74.90	Down to 75% = $27.20
12.5% Bending stress related costs....$12.50	Up to 110% =$13.90. Adjustment for joint effect =100% of $13.90 @ 200% = $27.80	Down to 90% = $10.20
11.1% Contact stress related costs....$11.10	No change = $11.10	No change $11.10
Sub-total..............$59.90	$113.80 (up to 190% of avg.)	$48.50 (down to 81%...)
40.1% Remainder of variable costs....$40.10	Up to 190% = $76.00	Down to 81% = $32.50
Total $100.00 (100%)	$190.00 (190%)	$81.00 (81%)

CALCULATION OF PERCENTAGES FOR POOR AND GOOD TRACK

Deflection	74.90/190.00 = 39.4%	27.20/81.00 = 33.5%
Bending Stress	27.80/190.00 = 13.6%	10.20/81.00 = 12.6%
Contact	11.10/190.00 = 5.9%	11.10/81.00 = 13.8%
Remainder	76.00/190.00 = 41.1%	48.50/81.00 = 40.2%

SUMMARY OF MW&S COSTS FOR A ROAD HAVING AVERAGE MW&S COSTS OF 76¢ PER 100 GROSS TON MILES; AVERAGE LOAD OF 54 TONS; AND 53% VARIABLE

	Average Track	Poor Track	Good Track
Variable MW&S Cost per 1000 gtm.	76¢	Up to 190% 144¢	Down to 81% 61.5¢
Constant MW&S Cost per 1000 gtm.	67¢	67¢	67¢
Percent Variable	53.0%	68.5%	48.0%

Fig. 9

POOR TRACK

TONS OF CAPACITY PER CAR	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130
53.0% OF VARIABLE COSTS RELATED TO DEFLECTION & BENDING	0.727%	→ ” ...						
5.9% OF VARIABLE COSTS RELATED TO RAIL CONTACT	0.16%	0.19%	0.34	1.30	4.95	4.30	1.96	1.03
41.1% OF VARIABLE COSTS REMAINING AS AVERAGE OF ABOVE	0.61%	0.68	0.70	0.76	1.02	1.07	0.89	0.76

TOTAL = 100% OF VARIABLE MW&S COST = 68.5% OF TOTAL MW&S COST.

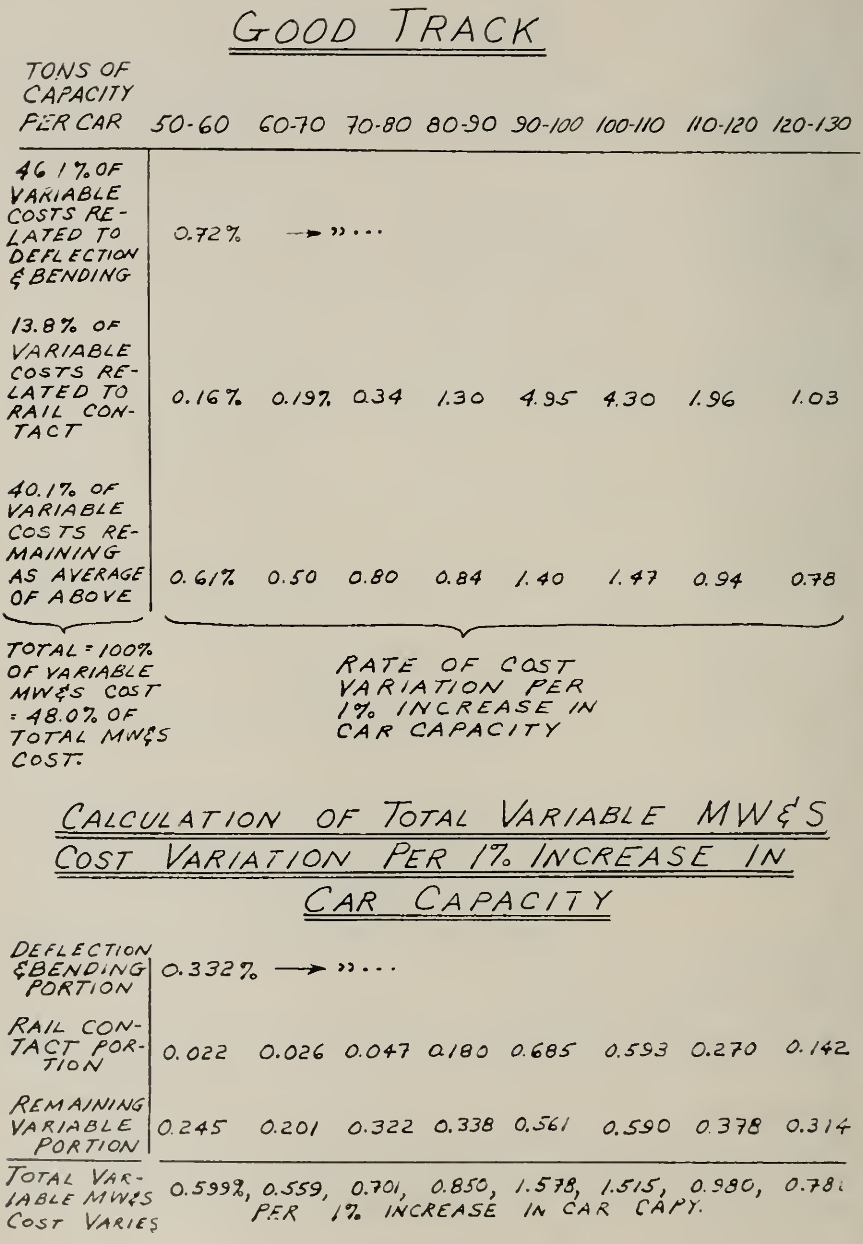
RATE OF COST VARIATION PER 1% INCREASE IN CAR CAPACITY

CALCULATION OF TOTAL VARIABLE MW&S COST VARIATION PER 1% INCREASE IN CAR CAPACITY

	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130
DEFLECTION & BENDING PORTION	0.381%	→ ” ...						
RAIL CONTACT PORTION	0.008	0.011	0.020	0.076	0.293	0.254	0.116	0.061
REMAINING VARIABLE PORTION	0.280	0.282	0.287	0.313	0.420	0.440	0.365	0.313
TOTAL VARIABLE MW&S COST VARIES	0.669%,	0.674,	0.688,	0.770,	1.094,	1.075,	0.862,	0.775,

PER 1% INCREASE IN CAR CAPY.

Fig. 10



GOOD TRACK

TONS OF CAPACITY PER CAR	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130
46 1% OF VARIABLE COSTS RELATED TO DEFLECTION & BENDING	0.72%	→ ״ . . .						
13.8% OF VARIABLE COSTS RELATED TO RAIL CONTACT	0.16%	0.19%	0.34	1.30	4.95	4.30	1.96	1.03
40.1% OF VARIABLE COSTS REMAINING AS AVERAGE OF ABOVE	0.61%	0.50	0.80	0.84	1.40	1.47	0.94	0.78

TOTAL = 100% OF VARIABLE MW&S COST = 48.0% OF TOTAL MW&S COST.

RATE OF COST VARIATION PER 1% INCREASE IN CAR CAPACITY

CALCULATION OF TOTAL VARIABLE MW&S COST VARIATION PER 1% INCREASE IN CAR CAPACITY

DEFLECTION & BENDING PORTION	0.332%	→ ״ . . .						
RAIL CONTACT PORTION	0.022	0.026	0.047	0.180	0.685	0.593	0.270	0.142
REMAINING VARIABLE PORTION	0.245	0.201	0.322	0.338	0.561	0.590	0.378	0.314
TOTAL VARIABLE MW&S COST VARIES	0.599%,	0.559,	0.701,	0.850,	1.578,	1.515,	0.980,	0.78

PER 1% INCREASE IN CAR CAPY.

Fig. 11

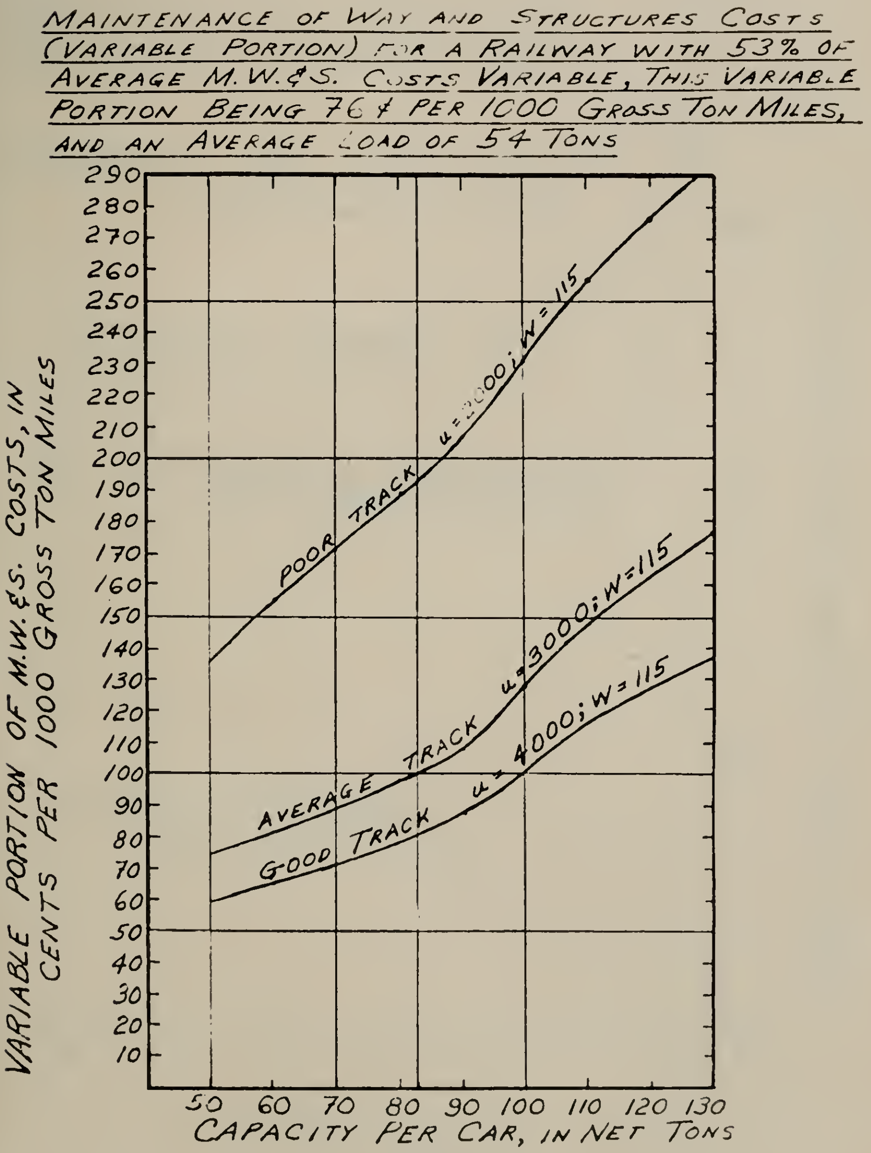

MAINTENANCE OF WAY AND STRUCTURES COSTS (VARIABLE PORTION) FOR A RAILWAY WITH 53% OF AVERAGE M.W.&S. COSTS VARIABLE, THIS VARIABLE PORTION BEING 76¢ PER 1000 GROSS TON MILES, AND AN AVERAGE LOAD OF 54 TONS
VARIABLE PORTION OF M.W.&S. COSTS, IN CENTS PER 1000 GROSS TON MILES
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
50
60
70
80
90
100
110
120
130
CAPACITY PER CAR, IN NET TONS
POOR TRACK u=2000; W=115
AVERAGE TRACK u=3000; W=115
GOOD TRACK u=4000; W=115

Fig. 12

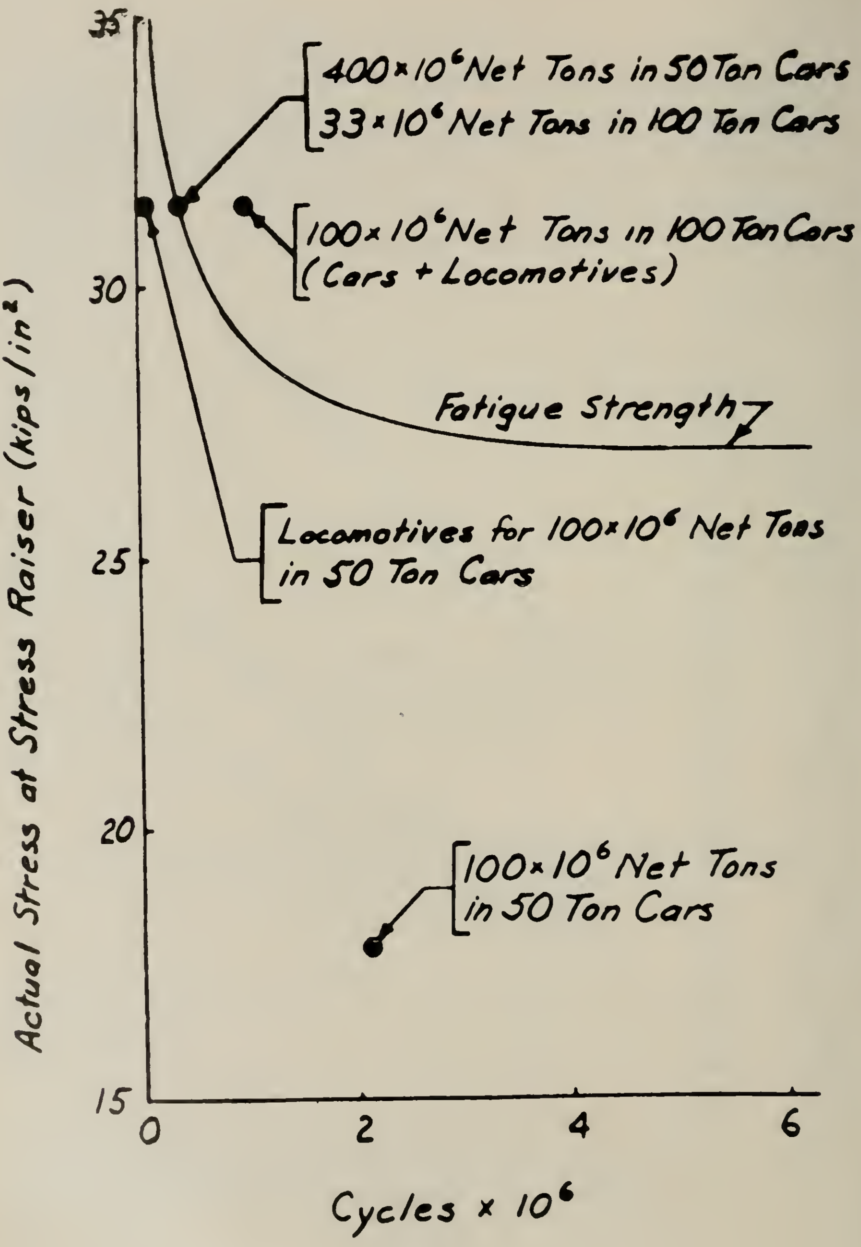

35
30
25
20
15
0
2
4
6
Actual Stress at Stress Raiser (kips/in²)
Cycles × 10⁶
400×10⁶ Net Tons in 50 Ton Cars
33×10⁶ Net Tons in 100 Ton Cars
100×10⁶ Net Tons in 100 Ton Cars
(Cars + Locomotives)
Fatigue Strength
Locomotives for 100×10⁶ Net Tons
in 50 Ton Cars
100×10⁶ Net Tons
in 50 Ton Cars

Fig. 13

INSTALLATION OF OFFICERS

Installation of Officers

President Bush: I would now like to install the newly elected officers of the Association. This is a short but important and impressive ceremony and will let each of you become more acquainted with the officers you have elected. So, with your permission, I will proceed with the installation ceremony.

To make room for new officers and directors a certain number of them complete their service on the Board of Direction each year. It is with mixed feelings that we see these changes take place.

I want to thank each member of the Board for his counsel, advice and support, and especially those members who, having completed their term of office, are retiring from the governing body of the Association. The close of this technical conference completes the services on the Board of Past President R. M. Brown, chief engineer, Union Pacific Railroad. The AREA constitution provides that past presidents will remain on the Board for two years after completion of their term as president. We are deeply indebted to Mr. Brown for his long and outstanding service to our Association—both in an official and an unofficial capacity—and, although he will be off the Board, I am sure he still will be called upon for counsel and advice as important matters come up.

Bob, will you please stand so we may give you the applause you so richly deserve.

(Applause)

President Bush (continuing): Other members of the AREA Board of Direction completing their term of service are these directors: B. G. Anderson, assistant vice president—engineering, Burlington Northern, Inc.; C. E. Weller, assistant vice president—engineering, Chicago, Rock Island & Pacific Railroad; and B. J. Gordon, chief engineering officer, Penn Central Transportation Company.

These men have served our Association well in their official capacity on the Board and I want to express our deep appreciation to each of them.

Will Messrs. Anderson, Weller and Gordon please stand and permit us to show our appreciation for their service.

(Applause)

President Bush (continuing): It is now my privilege and pleasure to present the new directors you have elected for the ensuing year. As I read your name, please come to the speaker's table through the walkway adjacent to the podium, and take a place at my right.

From the East: William Glavin, general manager, Grand Trunk Western Railroad.

From the West: E. H. Waring, chief engineer, Denver & Rio Grande Western Railroad, and G. H. Maxwell, system engineer of track, Union Pacific Railroad.

From Canada: R. L. Gray, chief engineer, Canadian National Railways. Gentlemen, I welcome you as directors of the American Railway Engineering Association. These are offices of high honor and responsibility you are assuming. I hope you will enjoy your service on the Board of Direction and will bring much value to its deliberations. Congratulations. You may be seated.

Our newly elected junior vice president is John Fox, assistant chief engineer, Canadian Pacific Rail. Mr. Fox, will you please come to the platform. Mr. Fox, I congratulate you upon your election as junior vice president and for your continued service on the Board of Direction.

We will now see what is probably the fastest promotion of an officer in AREA annals, but I assure you it is with greatly mixed feelings that this has to be done. According to the schedule, our new senior vice president was to have been W. J. (Jack) Jones, engineer maintenance of way and structures system, Southern Pacific Transportation Company. Unfortunately, a combination of circumstances beyond his control made it necessary for him to resign recently as vice president of the AREA and vice chairman of the AAR Engineering Division.

In view of this and in accordance with the AREA Constitution, the Board of Direction voted unanimously to advance John Fox to senior vice president of the AREA succeeding Mr. Jones. We are pleased to see Mr. Fox advance to this position but are most sorry to lose Mr. Jones in that position and from the Board of Direction. His always sound counsel and guidance will be greatly missed.

Mr. Fox, I will shake your hand again to cement your installation as senior vice president of the AREA.

Since that action by the Board left a vacancy in the junior vice president position, a person who had served as a director of the AREA had to be appointed to fill the vacancy in accordance with our constitution. Accordingly, the Board appointed B. J. Worley, vice president—chief engineer, Milwaukee Road, as junior vice president of the AREA. Mr. Worley, will you please come to the platform and take your place beside Mr. Fox. Mr. Worley, it is with much satisfaction that I see you advance to this position of greater responsibility in the AREA. I know from your past service on the governing body that you will discharge this greater responsibility with distinction.

You and Mr. Fox will make a splendid team of vice presidents. Please be seated.

Our new president is John T. Ward, senior assistant chief engineer, Seaboard Coast Line Railroad. To accord Mr. Ward proper recognition I have requested Past Presidents Hutcheson and Brown to escort him to the platform at this time.

Mr. Ward, I congratulate you upon your election to the highest position of honor in the American Railway Engineering Association. I share the confidence which has been placed in you by our membership and it is with pleasure and satisfaction that I turn over the responsibility of AREA President to you at the end of this meeting.

President Bush: We have now completed the scheduled program for the 74th Annual Technical Conference of the American Railway Engineering Association and the 1975 Annual Meeting of the Engineering Division, Association of American Railroads. You will be interested to know that the registration for our 1975 meetings is: railroad men, 419; non-railroad men, 466; total registration, 885.

It is now time to turn over the Association to our new president and to adjourn these meetings. Before doing so, however, I want to take this opportunity to thank all who contributed to the work of our Association during the past year and to the success of this Conference. The AREA has had a successful and productive year in spite of difficult conditions. This has happened because so many of you gave so generously of your time and effort, which I assure you, has been greatly appreciated.

There are so many to whom I am personally indebted that I cannot possibly name them all here, but I do want to express my personal appreciation for the splendid cooperation of our officers and directors, our committee chairmen and the active committee members, and all others who contributed in any way to the success of the 1974–1975 Association year. I especially want to express my sincere appreciation, and the appreciation of the Association to Earl Hodgkins and his staff for the manner in which they have conducted the affairs of the AREA during the past year.

Their attention to the multitude of details in the planning and execution of the many Association activities and programs, and their efforts in connection with the important, world-wide-used AREA publications, many times under most difficult circumstances, has been invaluable to the Association, the Board of Direction, and to me. They deserve the maximum extent of our support, patience and understanding.

The Conference Operating Committee, under the direction of its manager, Bruce Miller, Penn Central, did its usual outstanding job in connection with operating this Conference in accordance with the plans and arrangements made by the Association's staff. These well-planned and well-operated Conferences do not just happen. Other than our past presidents, few members are in a position to know the multitude of details handled by this committee during our Conferences and how easily things could go awry if it were not for their diligence.

I join Mrs. Bush in thanking all of these ladies who, with Mrs. Ward, Mrs. Fox, and Mrs. Hodgkins, gave so generously of their time in assisting with the functions of our Conference planned expressly for our wives. You have our grateful appreciation.

It now gives me great pleasure to formally install our new president, and I request him to join me at this podium.

Mr. Ward, I congratulate you upon your election to the highest position of honor in the American Railway Engineering Association, and I now proclaim you President. In taking this action, I also proclaim Mrs. Ward as the unofficial "First Lady" of the Association.

I share the confidence which has been placed in you by our membership and it is with pleasure and satisfaction that I turn over the responsibility of president to you.

In doing this, I want to present you with this gold pin, which bears the words engraved on the back:

J. T. Ward
President
1975–1976

This is the official emblem of the AREA and I am sure you will wear it with equal pleasure to yourself and honor to the Association.

President Ward: Before I adjourn this Conference, I would like to remind all members of the Board of Direction, including the retired members and new members, and all the members of the Conference Operating Committee, that we will have a joint luncheon together in the Wabash Parlor on the third floor of this hotel immediately following the adjournment of this meeting.

The luncheon will be followed by the post-Conference meeting of the AREA Board of Direction in Private Dining Room 9.

Is there any further business to come before the meeting?

(At this point AREA Past President T. B. Hutcheson (assistant vice president—engineering and maintenance of way, Seaboard Coast Line Railroad) asked the privilege of the floor and spoke as follows):

Mr. Hutcheson: The Raleigh & Gaston Railroad, incorporated in December 1835, began construction in 1836, and by 1840 completed its line from Gaston, North Carolina, a river port at the fall of the Roanoke River, to the state capital at Raleigh, North Carolina. It connected with the lines of the Petersburg Railroad and the Portsmouth & Roanoke Railroad, among the very earliest lines, respectively, in the Atlantic Coast Line system and the Seaboard Air Line system. Its purpose was to connect the capital of North Carolina and its surrounding area by rail and river with the flow of commerce along the eastern seaboard.

By 1860 the Raleigh & Gaston had prospered to the point of considering a permanent headquarters for the company, and in that year began construction of a general office building located a short distance east of the state capitol. Completed in 1862, during the War for the Southern Confederacy, in an Italian style popular in the period, the lovely headquarters building has served the Raleigh & Gaston Railroad and its successor companies to this day, a term of 113 years, as the principal office in Raleigh. It is one of the oldest commercial buildings in the state continuously used for its original purpose.

During this year the building will be sold to the State of North Carolina, and the land on which it sits will be used in the expansion of the State Government Center. It is hoped that the office building will be relocated in the capitol complex and preserved, since it is a building entered in May 6, 1970, on the National Register of Historic Places. The railroad division office will be relocated elsewhere in the city.

In January 1943, 81 years after the building was completed, your newly elected president entered the railroad industry by reporting to work in this building as an assistant to division engineer for Seaboard Air Line Railroad. Thus, the Raleigh & Gaston building and Raleigh, North Carolina, have continued to hold a warm place in his memory.

John Ward's talents for organization and administration and his outstanding abilities as an engineer were quickly recognized by his supervisors, and in 1947, four years later, he was moved to the chief engineer's office where those talents could be brought to a wider range of engineering and administration problems. He has served continuously in that office in positions of increasing responsibility, and in 1958 became assistant chief engineer for Seaboard Air Line. In 1967 he was appointed senior assistant chief engineer on the newly formed Seaboard Coast Line Railroad.

When it became apparent that John would succeed to high office in this Association, his good friend, Jessie Alcorn, then the division engineer at Raleigh, removed a portion of an original pine beam from the underpinnings of the old Raleigh & Gaston office building. John's associates in Seaboard Coast Line's engineering department, who are members of AREA, as a token of the high esteem in which he is held by all of us on Seaboard Coast Line, have had fashioned from it a gavel for his use in directing the affairs of the Association during his term as president.

John, it is with a great deal of pleasure that we present to you this gavel made from a timber installed in 1860 in the Raleigh office building. With it go the best wishes of your many friends and associates for a most successful term as president of AREA.

The gavel is inscribed, "John T. Ward, President, AREA, 1975–1976, from your friends on Seaboard Coast Line."

President Ward: Is there any further business to come before this meeting?

If not, I shall use this beautiful gavel which has been presented to me and declare the 74th Annual Technical Conference of the American Railway Engineering Association and the 1975 Annual Meeting of the Engineering Division, Association of American Railroads, adjourned.

AAR ENGINEERING DIVISION SESSION

Remarks by Division Chairman R. F. Bush*

The Annual Meeting of the Association of American Railroads Engineering Division is an important part of our Annual Technical Conference, and a very informative and inspiring program has been provided.

The Engineering Division is a part of the Operations and Maintenance Department of the AAR, reporting directly to R. R. Manion, Vice President of the Department. The Engineering Division General Committee is composed of the officers and directors of the American Railway Engineering Association and additional railroad representatives to total 21 members.

While we have completed our recommendation to the Federal Railroad Administration concerning track safety standards, we have several areas that may require additional study and possible revisions of the FRA Track Standards.

Some of the allowable speeds over detected rails containing a defect are too restrictive. The missing spike in the center joint tie of a supported joint should not, in my opinion, require a 10 mph slow order. These are but two of the examples of areas where, I believe, additional study and recommendations are required.

All of us are very familiar with the results of building new types of cars without proper testing on a test track to determine just what the characteristics of the car may be in regard to warp, curvature, superelevation, and rock-and-roll. We should have a closer working relationship among the AAR Engineering Division, the AAR Mechanical Division, AAR Research and Test Department, and the car builders. This would at least provide a general knowledge and evaluation of the car design and, more important, help determine ahead of time what its actions on a track will be when part of a train consist.

Another area of great concern to all of us is the present fuel shortage. The present indications are the problem will probably get worse as the non-renewable supply of crude oil is being exhausted. One partial solution of this problem is the gradual electrification of the railroads from coast to coast. Our government has several research groups: National Aeronautical and Space Administration, and the Atomic Research Commission, to name two, that could be given the basic problems of designing an electrical generating station using nuclear power. In order to assist the private electrical power companies and save years of parallel research and development, the plans and specifications could be given to the power companies to build the generating station required to produce the electrical energy. We have in the American Railway Engineering Association a Committee on Electrical Energy Utilization which provides a nucleus of talent to provide the plans and specifications for modern catenary and power transmission systems on the railroad properties.

President Ford and the Congress are concerned about ways of "priming the pump" to assist our sagging economy. Long-term, low-interest loans could be made by the government or guaranteed loans that could be repaid by the railroads and power companies from savings in fuel costs and earnings. The manufacture of the necessary hardware and equipment for both power plants and railroad installations and locomotives should offer a boost to the economy, to employment and to a group of the manufacturing industries.

Governor Shapp of Pennsylvania, as head of the Transportation Committee of the National Governors' Conference, has released a report on transportation suggestions. In the report, and I quote from the Harrisburg, Pa. Patriot, "electrification of railroads would save 60 million barrels of oil a year in the Northeast." Some of you may remember when the former Pennsylvania Railroad undertook just such a project in the early days of the depression nearly a half century ago. This, of course, was a much smaller endeavor and all with private funding.

---

* Chief Engineer, Erie Lackawanna Railway, Cleveland, Ohio.

We must play a part in the solution of the energy problem, and the sooner we start the sooner we will be assured of a continuing source of energy for the backbone of the American Transportation System—The American Railroads.

Evolution of Rail Steel and Rail Sections and What Is Being Done Relative to This Material Today

76–653–16

By K. W. SCHOENEBERG
Senior Research Engineer
Association of American Railroads

Rail is an integral and important part of the whole track system as are the ties, fasteners, plates, ballast and subgrade. However, rail can be considered to be a complex system in its own right. The elements of this system are comprised of the possible variations in design, chemistry, processing and use which sometimes present conflicting requirements on the rail. As a result, simple solutions to particular problems are not easily found. The effects of changes in individual elements of the system must be evaluated in terms of the effect on the overall system. Much research and testing work done over the years has attempted to identify and characterize the major elements of this system such as rail design (height, head, web and fillet, etc.), chemical composition, manufacturing processes, wear resistance, defects and, only recently, fracture properties.

Our purpose today is to discuss the historical aspect of rail design and rail steel composition in order to better understand what is needed and what is being done about some rail problems today.

RAIL DESIGN

History

The first running surfaces for early railroad rolling stock were strap rails comprised of cast-iron plates approximately 4 in by 1¼ in by 5 ft long, which were attached to a wooden base. The first strap rails were used around 1767. Various types of cast and malleable iron rails were used until 1820 when the first iron rails were rolled. These were supported by cast-iron holders, called chairs, attached to stone supports. In an effort to eliminate the use of the expensive chair required for this type of iron rail, a rail with a wide and relatively heavy flange on the bottom was rolled in 1831. Between the 1830's and 1858, various shapes were developed and rolled, but none seemed to prove serviceable, and a demand for more metal in the head for wear forced a final return in 1858–1868 to the T shape (Stevens) with a wide thin flange. From that time to the present, the rail section, as we know it, developed in design and weight.

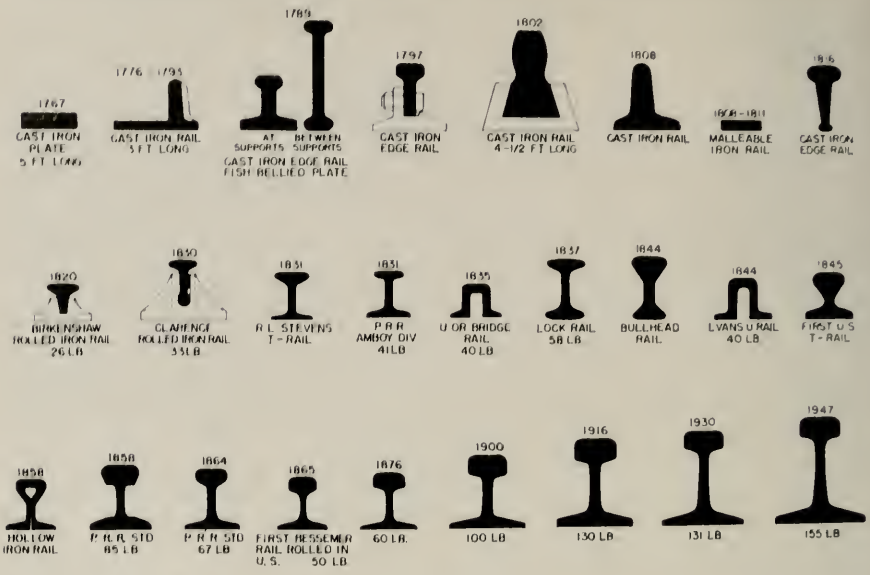
Several principles have governed rail design:

1. Rail should have adequate bending strength.
2. Provide a head or running surface which will resist wear for the longest practicable life.
3. Present a wide base for lateral stability and adequate bearing surface.
4. For the sake of economy, provide a proper balance between weight (cost) and stiffness (stability for maintenance of the track structure).

The American T-rail has best met all of these requirements and represents an acceptable design. (Quoting from Professor W. W. Hay) "It is of girder-like

---

Note: Discussion open until October 15, 1975.



shape resulting from its use, manner of fastening and economic considerations." The head, which is deep and narrow, has the top or running surface of such contour so as to conform to that of the average worn wheel tread running upon it. The base is broad enough to give the rail stable support on the tie plates or ties and with enough flange to facilitate being gripped by spikes or other hold-down devices. The web is of such design and contains enough material so as to support the wheel loads and provide rigidity without being wasteful of material. Important details such as service-induced stresses in the upper web and head fillet areas and the fishing or contact areas for joint bars, have governed the final design of section.

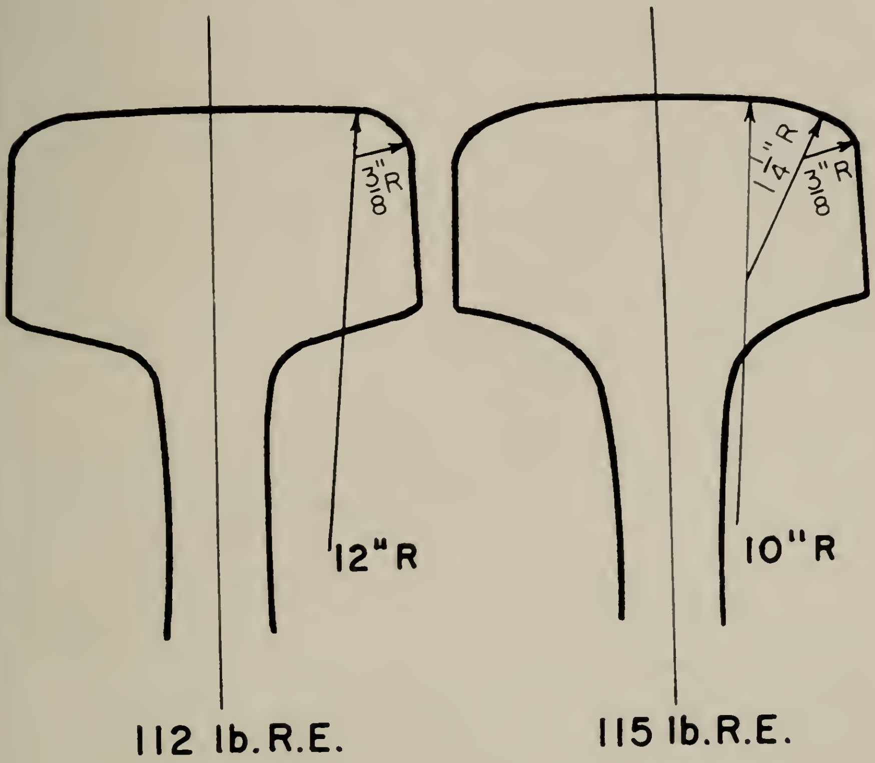
(Again quoting from Prof. Hay) "Rail design has not followed the rational methods usually found in the design of most engineering structures. This is due primarily to the many indeterminate factors which affect dynamic loading—nosing of locomotive and car wheels, condition of maintenance, materials and general elastic properties of the track structure." Changes in rail design have usually occurred as the result of failures or problem areas in existing designs. In the United States, the continual increase in axle loadings and train speeds have led to continuing rail design changes particularly with respect to the size and weight per yard. This took place from the early 1900's to about 1946 and 1947 when the heaviest sections of 140 lb and 155 lb per yard were rolled. Since 1947, some variations and new designs have been developed; the 112 TR and 129 TR (torsion-resisting) by the Chicago, Burlington & Quincy Railroad, the 106 CF&I, the 119 CF&I and 136 CF&I (now RE) by the CF&I Steel Corp., and the 122 CB by the Chesapeake & Ohio Railway/Baltimore and Ohio Railroad.

Evolution of Rail Design

Rail Height

Increasing the weight of a rail increases the moment of inertia or "stiffness" of the section, and this accounts for the higher rail weights in use today. Modern

RAIL HEAD DESIGN CHANGES



wheel loadings and train speeds have dictated the use of a much higher capacity type of structural member offering stiffer support to provide for economical maintenance of line and surface. Although an increase in the section weight results in greater stiffness, additional stiffness can also be obtained by increasing the section's moment of inertia by means of an increase in the height of the rail. An economy of metal can then be achieved by adjusting the shape of the cross section to give a maximum height of rail. The 131-lb, 132-lb and 133-lb sections exemplify designs of increased stiffness that resulted from a redesign of the 130-lb rail section, and which involved only nominal weight increases. The height was increased from 6¾ in (for the 130-lb rail) to 7⅛ in for the 131-lb and 132-lb rail and 7 1/16 in for the 133-lb rail. The solution to the problem of how to increase stiffness and beam strength was accomplished economically by means of a redesign of the section, which resulted in greater rail height, and not merely an addition of more metal and, therefore, weight.

Head Design

Early rail of the "T" rail design had a rolled "top-of-the-head" contour which was flatter with rather sharp, small radii gage corners. This head contour prevailed in the United States until the late 1940's, and in European countries as late as 1954 and 1955. The problem of plastic flow of the rail head metal towards the gage corner of the rail and the resultant shelling of the rail led to studies being made in this country, starting in 1942, to help solve this problem. Many sectional contours of rail in track were taken by the AAR's Engineering Division Research staff, and it was found from these contours that the effect of wheel wear was to create a uniform contour with a common pattern regardless of the initial contour to which the rail was rolled. The wear pattern tended towards a more rounded profile with a larger radius in the gage corner. This wear contour pattern initially cold-worked the metal in the gage corner of the rail which resulted in metal flow and the formation of a lip on the gage side. Since this cold working resulted in plastic flow and the creation of undesirable stresses in the gage corner location where shelly cracks develop, it seemed logical that the shelling problem could be reduced if the rail was initially rolled to a contour that reduced this cold-working to a minimum. Subsequent rail head designs of the 115-lb, 132-lb and 140-lb sections adopted this worn rail contour concept. This resulted in an improved contact area between new rail and the wheels.

Web and Fillet Design

The problem of upper fillet area and web cracks was recognized with concern when it developed with the 112-lb and 131-lb sections after several years of service life in track. The problem was studied by the Engineering Division of the AAR in 1944 and 1945. Experimental measurements of the web and fillet stresses indicated that maximum stresses were occurring near the bottom of the head and web fillet, and that the maximum stresses varied inversely as the radius of the fillet curvature. The wheel load is distributed into the web area of the rail as an average compressive stress, but the eccentricities of loading from the varying contact position of different wheels create a range in stress from high to low compression, of even a low tension in some instances.

High localized stresses of over 60,000 psi in compression in the upper web and fillet areas occur when the wheels bear eccentrically on the head, as is frequently the case. This occurs particularly on rail in curves, or where improper cant of the rail is present. The results of the study brought about a subsequent increase in the thickness of the upper web by increasing the fillet radii from ⅜ in. to ¾ in. This was incorporated in the redesign of the 112-lb and 131-lb sections and led to the adoption of the 115-lb and 132-lb sections in 1946. In the 115-lb rail design, the measured maximum localized stresses for the same conditions of loading were found to be 26 percent less than for the 112-lb rail section, because of the corrective measures taken in the upper web and fillet areas. This web and fillet area redesign also presented a considerable advantage in the requisite mill rolling techniques since it resulted in a more favorable stress distribution within the rail cross section. A similar fillet design has also been incorporated in the German S64 rail.

Location of Bolt Holes

The frequency of web failures within the joint bar area and especially through the bolt hole nearest the rail end presented a problem of increasing magnitude during the 1940's, and the adoption of the new rail sections in 1946 necessitated improvements in hole spacing for the new rail sections. In 1947, a study of the effects of bolt hole spacing on rail web stresses was conducted. It was concluded that a wider spacing between the bolt holes and rail ends reduces the maximum tensile stresses and possibility of fatigue failure. As a result, recommendations were made and adopted that the spacing for bolt holes at the rail ends be changed from 2½ in.–6½ in.–6½ in. to 3½ in.–6 in.–6 in. for six-hole joints, and from 2½ in.–6½ in. to 3½ in.–6 in. for four-hole joints. Progressive reductions in this type of rail failure in rail with the new bolt-hole spacing have been recorded since that time.

However, web failures within the joint bar area are still with us and continue to account for a good percentage of defective rails removed from track. Further studies in the 1950's revealed that bolt hole cracks emanated from stress raisers at the edge of the bolt hole. These are caused by improper drilling, drill gouges, burrs left from drilling and holes through the rail brand (raised letters). Tests have shown that proper treatment of the drilled hole by reaming, chamfering or peening could correct the origination of these bolt-hole crack defects.

Rail Length

When the first iron rails were rolled in the United States, their lengths were 15 ft, and by 1855 the first 30-ft rails were rolled. It was many years before any general demand for 30-ft rails was experienced, and it was 44 years before any increase was made in the standard rail length, that being to 33 ft in 1899. After 1925, a further increase took place in the length to 39 ft, which has remained the standard ever since. The restricting influences on rail length in the United States have been mill layouts and the capacity of the gondola cars used for rail transport. The control-cooling process utilizes boxes or containers that accommodate the 39-ft lengths of rail.

Chemical Composition and Manufacture

Composition

The chemical composition of rail steel conforms to the latest "Standard Specifications for Carbon Steel Rails" as listed in ASTM Designation A 1, and the "Specifications for Steel Rails" as listed in the current American Railway Engineering Association Specifications. These two specifications are identical, except that the ASTM specification, as compared to the AREA specification, omits the sulphur content and allows 0.02 percent less silicon at the upper limits.

These specifications depict a rather high range or percentage of carbon, and essentially bring out the fact that we on this continent have historically leaned to high-carbon steel for rail production. Again, historically, our higher wheel loads and desires for higher speeds resulted in a need for a steel of high hardness for good wear properties and maximum metal flow resistance. High amounts of carbon give this.

The chemical composition of rail steel has been changed many times over the years, involving various percentages of the constituents, particularly with respect to the carbon, manganese and silicon contents. These were mainly changed in an effort to resolve the problems of shelling experienced with rail in service. Many heats of rail steel were made with progressively increasing amounts of manganese and silicon, and other heats were made with special added elements, alloys such as vanadium, chromium, columbium (niobium) and/or titanium. Varying amounts of carbon were also tried in combination with these other elements. This was an effort to produce a tougher and stronger steel which would resist plastic deformation and head flow and retard the development of shelling. Some success

AREA SPECIFICATIONS
NOMINAL WEIGHT IN POUNDS PER YARD

CONSTITUENT (PERCENT)	70/80	81/90	91/120	121/OVER
CARBON	0.55 - 0.68	0.64 - 0.77	0.67 - 0.80	0.69 - 0.82
MANGANESE	0.60 - 0.90	0.60 - 0.90	0.70 - 1.00	0.70 - 1.00
PHOSPHORUS, MAX.	0.04	0.04	0.04	0.04
SULPHUR, MAX.	0.05	0.05	0.05	0.05
SILICON	0.10 - 0.25	0.10 - 0.25	0.10 - 0.25	0.10 - 0.25

was achieved in retarding the development of shells in rail with a concurrent increase in rail life. However, shelling still occurred, and is still occurring at an alarming rate.

Another effort in this direction was the heat-treating of rail. This also had the desired effect of strengthening the rail not only to resist shelling but reduce rail abrasion or wear as well. It increased the time span to two and three times, and even more in some cases, before shelling occurred. In addition to heat-treating the full cross-section of the rail, much work has been done in heat-treating for hardening only the top and sides of the rail head. This has been accomplished by flame or induction hardening techniques.

As far as the present day chemical composition of rail steel is concerned, two types of rail steel have been used in an effort to combat the early development of shelling, these being "high-silicon" and "intermediate manganese" rail steel. Where the specified percentage of silicon in carbon-steel rail ranges from 0.10 to 0.25 percent, the corresponding range in high-silicon rail is from 0.50 to 1.00 percent. The intermediate manganese rail has a percentage of manganese of about 1.30 to 1.60 percent with a corresponding reduction in carbon.

In recent years, another effort to improve our rail quality with the addition of alloying elements has been made mainly by our Canadian railroad friends and the two Canadian rail producers. These are with the addition of manganese–vanadium and chromium. Chromium-molybdenum rails are being produced here in the U. S. for test on an Australian mining railroad.

Manufacture

Since about 1900, rail mills have undergone many changes, because of economic trends, steel making technological progress and the increasing requirements of the railroads with respect to quality of the steel, size of the rail section, length of rail, freedom from internal and surface defects, dimensional exactness and a variable demand regarding quantity. At the end of 1957, there were nine mills in the United States and Canada that were producing railroad rails. In 1958, the

Carnegie Mill of U. S. Steel Corporation and the Inland Steel Company mill discontinued rail production, and today there are five mills in the United States and two mills in Canada that remain as the rail producers.

The one outstanding technological change in rail making came about in 1937 with the adoption of the control-cooling process. This process prevents shatter cracks through which many transverse fissure type defects developed.

Several recent modern processes and advancements in steelmaking technology are being used in the production of rail steel. One of these is the continuous strand caster which molds steel slabs or billets directly from liquid metal. The steel is poured from the bottom of the ladle into a tundish, a special reservoir for the molten steel located on top of the casting machine. The steel flows from the tundish into a water-cooled mold, passes down through a roller and cooling chamber, like red-hot strips of taffy, and finally emerges as cast slabs or shapes. The continuous castings are cut into blooms and then cooled. Then they are reheated and go on to the rolling mill for rolling into rail. This process eliminates the use of ingots, and therefore, gives promise of eliminating pipe and segregation conditions prevalent in rail produced by the ingot process.

Another development in steelmaking technology that is used in rail steel manufacture involves vacuum degassing. In this process, the molten steel is fed from the ladle into a heated vacuum chamber where the vacuum draws undesirable gases, such as hydrogen, from the molten steel, thus improving its metallurgical properties. This process reduces the hydrogen level that may cause shatter cracks and lead eventually to transverse fissures in the rail. Vacuum degassing accomplishes essentially the same objective that control-cooling does, and therefore may eventually eliminate the control-cooling process in rail making which has been one important factor in the length of rail that is produced. One rail producer in Canada is now making 78-ft rail by vacuum degassing the rail steel.

In review, at this point in time, we can note that as far as the design or the structural integrity of rail is concerned, it is adequate. It has been for some time and seemingly no present-day problem with rail reflects on its design. It appears that the problems of the day have mainly to do with the composition of the rail steel, the materials used in making it and how it is made, and how the final product, rail, is made. We can repeat the statement made years ago relative to rail steel when results of studies of shelling revealed "shelling is primarily caused by heavy bearing pressures of car wheels on a small area of contact on the rail head which produce plastic flow and internal shearing stresses that exceed the capacity of the steel to withstand such stresses."

Our rail research and problem-solving efforts today then are primarily being directed towards improvements in the steel—in trying to improve the load-carrying capacity of the steel as well as seeking ways and materials to combat defect formation and propagation; in short, to improve the fracture toughness of the steel.

On-Going AAR Rail Research

Fracture Toughness Testing

The fracture toughness testing of presently used and experimental carbon-steel, alloy-steel and heat-treated railway rails has been completed. Twelve types of rail steel were analyzed.

CHEMICAL COMPOSITION OF RAILS INVESTIGATED

SPECIMEN NO.	RAIL TYPE	C	Mn	P	S	Si	Ni	Cr	Mo	V
1	AREA CONTROL-COOLED SPECIFIED VALUES	0.81 0.69-0.82	0.87 0.70-1.00	0.013 0.040	0.018 0.05	0.17 0.10-0.25				
2	BS 11 BRITISH STANDARD SPECIFIED VALUES	0.43 0.50-0.60	1.19 0.95-1.25	0.030 0.060	0.038 0.060	0.12 0.35				
3	HIGH SILICON	0.75	0.78	0.028	0.030	0.49	0.08	0.05	0.05	
4	INTERMEDIATE MANGANESE	0.65	1.37	0.027	0.032	0.19	0.05	0.05	0.05	
5	MANGANESE-VANADIUM	0.69	1.83	0.006	0.035	0.24	0.05	0.59	0.05	0.12
6	CHROMIUM	0.72	0.78	0.012	0.029	0.27	0.05	1.31	0.05	
7	CHROMIUM-MOLYBDENUM	0.73	1.14	0.019	0.033	0.20	0.05	0.76	0.17	
8	CHROMIUM WITH HYPERCAL	0.75	0.87	0.019	0.028	0.30	0.07	0.73	0.20	
9	OIL QUENCHED (F.H.T.)	0.76	0.93	0.013	0.034	0.18				
10	INDUCTION HARDENED	0.75	0.83	0.013	0.028	0.09				
11	BRITISH EN-15	0.41	1.42	0.031	0.037	0.21				
12	BRITISH EN-15 HIGH-SILICON	0.36	1.49	0.024	0.016	0.92				

TENSILE PROPERTIES OF RAILS*

SPECIMEN NO.	RAIL TYPE	0.2 YIELD STRENGTH (Ksi)	ULTIMATE TENSILE STRENGTH (Ksi)	ELONGATION (Pct.)	RED. OF AREA (Pct.)
1	AREA CONTROL COOLED	69.9	135.9	9.5	11.9
2	BS 11 BRITISH STANDARD	67.6	108.0	19.7	45.0
3	HIGH SILICON	70.8	137.0	10.3	12.3
4	INTERMEDIATE MANGANESE	76.2	133.4	13.5	26.1
5	MANGANESE-VANADIUM	99.9	163.3	10.2	21.8
6	CHROMIUM	94.9	161.6	9.2	19.8
7	CHROMIUM-MOLYBDENUM	108.9	172.9	9.5	20.2
8	CHROMIUM WITH HYPERCAL	106.6	167.5	11.5	23.7
9	OIL QUENCHED (F.H.T.)	126.1	176.9	12.6	29.1
10	INDUCTION HARDENED	118.4	174.3	13.2	33.7
11	BRITISH EN-15	56.1	102.6	25.5	53.0
12	BRITISH EN-15 HIGH-SILICON	57.1	100.0	24.0	57.4

* AVERAGE OF TWO TESTS AT 75F (24C)

Carbon-Steel Rails

Two carbon-steel rails were evaluated. Rail No. 1 was a 132-lb AREA standard carbon-steel control-cooled rail. Rail No. 2 was a British BS-11 standard carbon-steel rail. The major difference between these rails is the carbon content, with rail No. 1 containing 0.81 weight percent and rail No. 2 containing 0.43 weight percent.

Alloy-Steel Rails

Six alloy-steel rails were investigated. All of these rails were developed to provide rails with higher hardness, tensile strengths, and yield strengths to reduce wear and rail head plastic flow with the resulting reduction in shelling. The high-silicon, intermediate-manganese, manganese-vanadium and chromium rails produce higher tensile and hardness levels by solid solution strengthening. The chromium-molybdenum rails were developed to retard the transformation of the steel during cooling so as to produce a fine pearlite structure similar to that of the heat-treated rails during cooling after rolling. These rails will be used on the Mt. Newman Mining Co. iron ore railway in Australia. Two chromium-molybdenum rails were evaluated. One rail is made by conventional practice. The other rail has had a calcium compound (Hypercal) added to the ingot during pouring. The calcium addition was made to control the size and shape of the manganese sulfide inclusions in order to reduce their tendency to nucleate fatigue cracks.

Heat-Treated Rails

Four heat-treated rails were investigated. The oil-quenched and the induction-hardened rails are widely used in the United States in track subjected to heavy wear. Both types of rails are treated to produce a fine pearlite structure. The oil-quenched rails are fully treated, and the induction-hardened rails are treated so as to develop higher hardness in the top and sides of the rail head. Two experimental British rails were also evaluated. These rails were specifically developed to give high fracture toughness. The improved fracture toughness is developed by the low carbon content, and by refining the grain size by aluminum nitride precipitation and normalizing after rolling. The originally developed composition and a high-silicon variation were evaluated.

Tension Tests

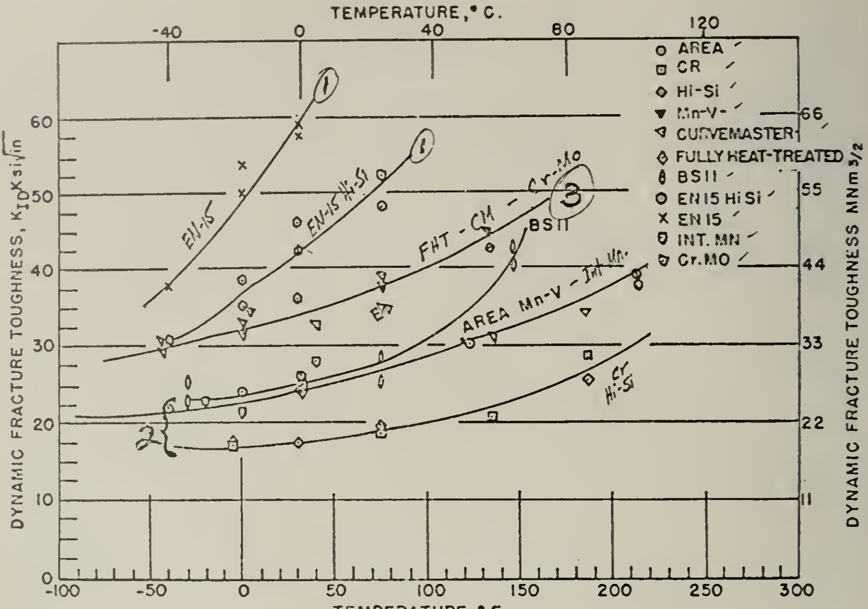
From the results of the tension steels the steels can be grouped into three categories:

1. The low-strength, high-ductility ferrite-pearlite mixtures represented by the British steels, No. 2, 11 and 12. These steels have ultimate tensile strengths in the 100 ksi range and reductions of area of greater than 45 percent.
2. The medium-strength, low-ductility, coarse pearlite steels represented by steels 1, 3, and 4. These steels have ultimate tensile strengths in the 135 ksi range.
3. The high strength, medium-ductility steels represented by steels 5, 6, 7, 8, 9, and 10 having tensile strengths in excess of 160 ksi. It should be noted that presence of chromium lowers the fracture ductility when compared to the other chromium-free rails with a fine pearlite structure.

Dynamic Fracture Toughness

From the results of the dynamic fracture toughness tests, as from the tensile results, the rail can be grouped into three categories:

1. The low-strength, high-ductility, ferrite-pearlite steels represented by steels 2, 11, and 12. Steels 11 and 12 are the British rail steels developed specifically to have high fracture toughness. The results show that these steels not only have high fracture toughness, but may not ever fracture in a brittle manner at temperatures above 30 F (0 C). The fracture properties of the BS-11 standard British rail steel are the same as those of the AREA standard rail steel up to 75 F (24 C). Above 75 F (24 C) the



THE DYNAMIC FRACTURE TOUGHNESS OF RAIL STEELS AS A FUNCTION OF TEMPERATURE

BS-11 toughness increases more rapidly than the AREA standard. At a temperature of 140 F (60 C) the BS-11 specimens used in this investigation fail after yielding. Such behavior does not occur in the AREA standard rail steel until 390 F (200 C).

2. The steels with coarse pearlite structures are represented by steels 1, 3, 4, 5, and 6. The high-silicon, manganese-vanadium, intermediate-manganese and chromium rails have higher tensile strengths than the AREA control-cooled rail, but depending on the alloying element used to increase tensile strength some reduction of fracture toughness may result. Carbon in excess of 0.5 weight percent to 0.8 weight percent does not affect the fracture toughness; it is well known that decreasing carbon below 0.5 weight percent will dramatically improve the fracture toughness. Manganese from 0.90 to 1.70 weight percent also shows no effect of changing fracture toughness. Chromium and silicon both tend to decrease fracture toughness as both elements increase.
3. High-strength, medium-ductility steels with a fine pearlite structure are represented by the heat-treated rail steels and the chromium-molybdenum steels. These steels show a fracture toughness that is nominally higher than the AREA standard rail steel. The effect of increased fracture toughness with decreasing pearlite colony size has been shown in earlier work sponsored by the AAR.

Our program of field evaluation of some of these types of rails such as fully heat-treated, Curvemaster, Hi-Si, intermediate manganese and standard is continu-

Test vehicle to develop improvements in ultrasonic testing for rail defects.

ing. These types of rail have shown potential for improvement in performance toward wear resistance and retarding the advent of shelling in curves. Percentages of loss of rail head material are being used to develop rail wear equations for the various types and this will be correlated with tonnage, speed, degree of curve and track environment factors.

The AISI-AREA-AAR Cooperative Rail Research Program has twofold objectives: first, to gather rail failure statistics and second, to determine the probability of rail failure on the basis of metallurgical properties. About 84 defect rail specimens have been collected from field test sites on four cooperating railroads. The rail specimens collected have been sorted, broken open and photographed, and identified at the AAR Technical Center. Specimens are being made for tensile and impact tests. Approximately 400 specimens have already been machined. Also, 30 to 40 rails will be selected for a complete metallurgical analysis. In addition, statistics on rail failure versus tonnage are being developed. Later stages of the program will involve determination of rail stresses, rail fracture toughness properties and their correlation to defect formation and propagation.

In an investigation to evaluate the fracture toughness of several British rail compositions, in particular EN-15 rail (which has superior fracture properties) and BS-11 rail (standard British rail steel), investigations of fracture toughness and metallurgical properties have been completed, as already noted. To determine the ability of these steels to resist shelling and crushing, rolling-load tests were also performed. This project is about completed.

Rail-Defect Detection

Another project currently on-going is to develop improvements in ultrasonic testing for rail defects by determining the trade-offs among vehicle speed, flaw location, flaw size and orientation. This is to be accomplished by developing a test vehicle and operating it in a field environment, while making changes to the hardware configuration. A test vehicle (Jeep Wagoneer) and related hardware has been received. Assembly of the system is continuing with the installation of components onto the probe carriages.

Another investigation ongoing at the laboratory involves the feasibility of detecting weld defects by the acoustical emission technique. Analysis of the data gathered at the Union Pacific Laramie welding plant show that there exist distinct signal levels between flawed and good welds. The final report on this test series has been completed by the Acoustics Emission Technology Corporation which performed the investigation. The metallurgical data developed at the Technical Center has been incorporated and the final report is being completed. A proposal from Acoustic Emission Technology has been received for the second phase. Arrangements for applying the technique for monitoring plant and field welds are being made. Testing will be started very soon.

Fracture Mechanics and Plane Strain Fracture Toughness of Cast Steels

76–653–17

By P. F. WIESER,[1] M. T. GROVES,[2] and J. F. WALLACE[3]

Introduction

Fracture mechanics has advanced to a point of real significance in engineering considerations of the prevention of brittle failure. Initial research and applications were largely limited to exotic, space exploration efforts[1-3]. The fracture mechanics approach, however, soon extended from the unusual applications, frequently involving high-strength materials to intermediate- and low-strength materials. Examples are to be found in the design and construction of pressure vessels[4-7]. Fracture mechanics concepts are also incorporated into the ASME pressure vessel code, an important document which regulates the construction of large, heavy-walled pressure vessels of the type employed in the nuclear power industry[8]. Fracture mechanics is presently gaining significance in a wider variety of structural design considerations[9-13].

A basic assumption in linear fracture mechanics is the presence of a crack or a crack-like defect. Fracture mechanics then, under conditions of plane strain, relates the stress intensity in the vicinity of that crack to the nominal stress applied on the structure and to the size of the defect that will become unstable, propagate rapidly, and thereby cause brittle fracture. Conversely, fracture mechanics defines the critical applied stress above which brittle fracture occurs. To the manufacturer of materials of construction, such as cast steel, an equally important aspect of fracture mechanics is its ability to define the minimum defect size that components should be inspected for[7]. Using fracture mechanics for the evaluation of inspection needs will likely result in abandoning the "best workmanship" approach. Shorter delivery times, and lower component cost may result in many instances.

The critical stress intensity in the vicinity of the crack tip is designated K_{Ic} under plane strain conditions. This stress intensity factor is a material property which represents the materials' inherent resistance to failure in the presence of a crack-like defect. Brittle failure results from any combination of applied load, crack geometry and size that yields a stress-intensity equal to or greater than K_{Ic}.

Temperature, mechanical and metallurgical variables influence the critical stress intensity, or plane strain fracture toughness K_{Ic}. The grain directions in rolled plate and forgings[14] may result in anisotropy of K_{Ic}[15,16] while castings are generally considered isotropic (Fig. 1a). Tiffany and Masters, therefore, indicate the need for K_{Ic} measurements of rolled forged Y rings in as many as six directions (Fig. 1b)[15]. Nonmetallic inclusions, increasing sulfur and phosphorus contents decrease fracture toughness[17-19].

---

[1] Research Director, Steel Founders' Society of America.

[2] T.R.W.—Baldwin Laboratory.

[3] Professor of Metallurgy and Chairman, Case Western Reserve University.

Note: Discussion open until October 15, 1975.

Applications of Fracture Mechanics

Realistic fracture prevention plans involve not only the critical flaw size but extend from the subcritical size. They involve inspection limits, tolerable flaw sizes, as well as the critical flaw size which may be reached in fatigue as a result of cylic loading (Fig. 2)(5). Literature references to applications of fracture mechanics for brittle failure prevention are especially numerous in situations of thin-wall gas-storage pressure vessels and heavy-section pressure vessels used in electric power, particularly nuclear power plants. Steel castings play an important role in the construction of power plants. An example involving the widely used cast carbon steel grade ASTM, A 216, WCC was therefore selected to illustrate fracture mechanics applications(7). K_{Ic} and yield strength values of this steel are shown in Fig. 3.

The critical stress intensity, K_{Ic}, near a disc-shaped flaw relates to the nominal applied stress, σ, and the flaw diameter, a, as follows:

$$K_{Ic}^2 = \pi\sigma^2\left(\frac{a}{Q}\right) \quad . \; . \; . \text{ for internal flaws}$$

$$K_{Ic}^2 = 1.21\,\pi\sigma^2\left(\frac{a}{Q}\right) \quad . \; . \; . \text{ for surface flaws}$$

Graphical solutions for these equations are shown in Figs. 4 and 5 in terms of the nominal stress and a/Q. Q is the flaw shape parameter for which solutions have been developed as shown in Fig. 6.

Calculations show that surface cracks must be huge, exceeding the wall thickness of most castings at normal operating temperatures. This fact simply indicates that brittle failure will not occur except in the presence of very large cracks. The length of through wall cracks is shown in Table I. Defects of the magnitude in Table I are unlikely in castings. Smaller cracks, however, may grow to critical size as a result of cyclic loading.

Fatigue crack growth rates, da/dN, are shown in Fig. 7 for the cast grade A 217, WCC as a function of stress intensity, ΔK, which is applied in each cycle. These data fit the generalized fatigue crack growth rate law(20):

$$\frac{da}{dN} = C_o \Delta K^n$$

A 10-inch-thick casting containing a crack that has grown to 5 in. depth or half thickness may be considered having completed its useful life—whether it fails by brittle fracture or merely bulging. The initial size of a flaw that will grow to the above dimensions can be calculated for any number of stress cycles in order to relate useful service life to the flaw size that must be inspected for. Greenberg et al(7) calculated these initial flaw sizes for the cast grade A 216, WCC (Table II) and showed that applications involving less than 10,000 cycles need not be concerned with cyclic crack growth. Very small initial flaw sizes are computed at 100,000 cycles, but castings for these applications are stressed very lightly.

Computations of the type discussed here have been developed further(5) and expanded to include weld repaired or fabrication welded material as well as the heat-affected zone of the base metal. Similar calculations are also illustrated in a most recent report(21) for thin-walled gas-storage pressure tanks. The example illustrated in this publication(21) involves tanks that were reclaimed from a surplus Atlas missile launch facility and evaluated for their new service as high-pressure air tanks in an ultra-high-velocity aero-dynamic and propulsion test unit.

Table I—Critical crack lengths of through-wall cracks in A 216 (WCC Grade) steel castings (7)

Temp. F	K_{I_c} ksi $\sqrt{\text{in.}}$	At 50% YS, 20 ksi	At 67% YS 27 ksi	At YS, 40 ksi
−50	60	5.8 in.	3.2 in.	1.4 in.
0	110	19.2 in.	10.8 In.	4.8 in.
50	150	36.4 in.	19.6 in.	8.9 in.

Note: Twice the wall thickness indicates leak before fracture

Table II—Initial surface flaw sizes, which will grow to a 5-in. depth in A 216 (WCC Grade) steel castings as a result of cyclic stress at room temperature (7).

	Initial flaw size, depth × length, in.			
	No. of cycles			
Cyclic stress (0 to max)	100	1000	10000	100,000
20 ksi (½ YS)	5 × 50	5 × 50	3.6 × 36	0.65 × 6.5
27 ksi (⅔ YS)	5 × 50	4.9 × 49	2.4 × 24	0.17 × 1.7
40 ksi (YS)	4.9 × 49	4 × 40	0.9 × 9	0.02 × 0.2

Cast Steel Fracture Toughness

Experimental work was conducted to determine the fracture toughness behavior of cast steels over a wide range of strengths. Notch bend specimens measuring 3 x 6 x 26 in. and 5 x 10 x 48.5 in. were machined from AISI 4335 and AISI 9535 steel castings following removal of risers and gates (Fig. 8). Strength levels ranged from an ultimate tensile strength of 124 to 210 ksi depending on the type of heat treatment and composition (Table III). Details of the procedures will be discussed in a future publication.

The through quenched nominal composition 4335 heats, with tempered martensite microstructure had K_{Ic} values ranging from 8.15 ksi·in.$^{\frac{1}{2}}$ at a yield strength of 173 ksi to 105.4 ksi·in.$^{\frac{1}{2}}$ at a yield strength of 158 ksi. Crack size factors, $(K_{Ic}/\text{y.s.})^2$, ranged from 0.223 at the higher strength level to 0.442 at the lower strength level. An increase in K_{Ic} or crack size factor with decreasing yield stress is typical for a given alloy and heat treatment (Fig. 9). These steels exhibited typical quenched and tempered martensite structures at the center of the notch bend specimen (3-in. thickness for 4335 steel). The through quenched steels of nominal composition exhibited indications of ductility by the fibrous appearance of the fracture surfaces. Propagation of the fracture was accompanied by the formation of shear lips (Fig. 10).

Slack quenched 4335 steel of nominal composition exhibited non-martensitic transformation products and therefore lower strength and toughness. These K_{Ic} values varied from 84.7 ksi·in.$^{\frac{1}{2}}$ at a yield strength of 126 ksi to 95.8 ksi·in.$^{\frac{1}{2}}$ at 131 ksi. Fig. 9 shows that fracture toughness values of slack quenched steels fall below those that would be expected of through quenched material at equivalent yield

Table III—Summary of composition and mechanical properties, cast low-alloy steels.

			Composition - %										Tensile and
	Heat No.		C	Mn	Si	Ni	Cr	Mo	S	P	Acid Sol. Al	U.T.S. ksi	2% Y.S. ksi
A)	AISI	4335:	Quenched and Tempered										
	41		.37	.87	.34	1.87	.79	.33	.026	.013	.028	186	173
	33		.37	.92	.32	2.00	.93	.39	.029	.023	.040	181	169
	25		.34	.87	.20	2.00	.85	.30	.019	.012	029	166	158
	43		.36	.99	.26	1.92	.83	.32	.024	.015	.034	169	156
	3		.39	.76	.17	1.90	.86	.31	.015	.014	.067	104	76
B)	AISI	4335:	Slack Quenched and Tempered										
	22		.33	.78	.20	1.87	.82	.30	—	—	.034	155	131
	23		.34	.80	.20	1.88	.77	.26	.019	.014	.022	150	128
	18		.34	.80	.23	1.83	.76	.26	—	—	.036	147	126
	24		.30	.77	.20	1.82	.77	.29	—	—	.040	141	118
	26		.36	.72	.20	1.90	.89	.30	.024	.012	.047	136	108
C)	AISI	4335:	Quenched and Tempered, High Aluminum										
	7		.33	.78	.21	1.50	.75	.26	.018	.014	.090	210	205
	8		.34	.90	.23	1.75	.88	.30	.019	.016	.130	196	192
	10		.35	.90	.26	2.10	.92	.40	.019	.016	.085	188	184
	9		.30	.72	.20	2.12	.96	.35	.017	.015	.075	173	175
D)	AISI	4335:	Quenched and Tempered, High Sulfur and Phosphorus										
	39		.37	.83	.25	1.75	.75	.30	.025	.046	.045	161	157
	32		.30	.80	.25	2.12	.80	.32	.066	.066	.046	155	156
	31		.29	.76	.30	1.82	.71	.28	.040	.044	.030	159	154
	40		.29	.74	.30	1.87	.75	.31	.050	.056	.049	157	152
E)	AISI	9535:	Normalized and Tempered										
	13		.33	1.75	.80	.66	.77	.46	—	—	.078	124	109
	27		.41	1.50	.60	.69	.65	.38	—	—	.049	125	89

(1) Hardness reported as Rc except where indicated as R_A

(2) Average of two tests, details in Table A1 of Appendix A

strengths. Improved toughness is obtained by through quenching at equivalent strength. The fracture surfaces of the slack quenched specimens had a rough, faceted appearance with somewhat larger shear lips than in nominal composition, through quenched specimens. These larger shear lips result from the lower yield strength of the slack quenched steel (Fig. 10).

Aluminum nitride embrittled heats of nominal 4335 composition exhibit K_{Ic} results that appear on first glance to be inconsistent with previous experience. These heats had a martensitic structure and K_{Ic} values ranging from 82 $\text{ksi}\cdot\text{in.}^{\frac{1}{2}}$ at a yield strength of 205 ksi to 91.9 $\text{ksi}\cdot\text{in.}^{\frac{1}{2}}$ at a yield strength of 175 ksi. The usual trend of increasing fracture toughness with decreasing yield strength is also noted (Fig. 9).

Aluminum nitride embrittlement has traditionally been associated with low toughness. K_{Ic} data obtained in the present investigation, however, indicate that under conditions of the high mechanical constraint present in the plane strain fracture toughness test, aluminum nitride embrittlement does not decrease toughness. This difference in behavior is rationalized by the difference between the tensile and impact tests on one hand and plane strain fracture toughness tests on the other. In both the tensile test and the Charpy impact test, considerable plasticity can be involved in the fracture process. Plastic flow in a tensile test allows the fracture path to seek out embrittling constituents such as areas containing aluminum nitrides. In a Charpy test specimen, the fracture area is predetermined by the position of the notch. If the area beneath the root of the notch in a particular specimen does not contain aluminum nitride precipitates, then the absorbed energy value obtained from this specimen would not reflect the presence of aluminum nitrides in the casting from which the specimen was removed.

Under plane strain conditions of a fracture toughness test, the plastic flow is severely limited at the crack tip. Only a small amount of plasticity, therefore,

Hardness Properties			Plane Strain Fracture		Charpy V-Notch Properties					Dynamic Tear Properties	
El. %	R.A. %	Rc(1)	K_{Ic} ksi$\sqrt{in}$	$\left(\frac{K_{Ic}}{Y.S.}\right)^2$	$E_{cv\text{-}76°F}$ ft·lbs	$E_{cv\text{-}max}$ ft·lbs	FATT-100 °F	Lat. Exp. at 75°F mils	$\frac{E_{cv\text{-}76°F}}{Y.S.}$	DTTE-80°F ft·lbs	$\frac{DTTE\text{-}80°F}{Y.S.}$
10.6	28.8	41	81.5(2)	.223(2)	6	14	212	3	.0503	—	–
5.9	14.3	39	84.1	.248	9	17	157	1	.0713	54	.319
8.0	17.2	37	105.4	.442	26	32	75	14	.1609	191	1.167
9.4	19.6	37	95.9(2)	.329(2)	11	21	150	4	.0705	—	—
10.6	23.7	59 R_A	—	—	35	70	>310	22	—	264	.348
10.6	25.4	33	95.8(2)	.537(2)	19	36	250	11	.1455	—	—
11.5	37.0	32	94.7	.551	16	32	265	8	.1253	111	.869
5.8	24.1	31	84.7(2)	.452(2)	14	38	265	7	.1108	—	—
6.0	18.6	28	87.1	.543	18	40	212	10	.1524	108	.914
11.0	26.9	28	62.4	.332	15	36	265	9	.1384	76	.701
3.5	6.0	43	82.0	.160	10	11	>310	2	.0487	—	—
1.6	5.2	42	82.3	.184	—	—	—	—	—	88	.452
2.8	6.5	41	86.2	.220	—	—	—	—	—	104	.522
1.7	5.8	40	91.9(2)	.277(2)	13	20	125	1	.1414	—	—
3.6	6.0	36	66.9(2)	.181(2)	4	10	>310	0	.0222	—	—
2.3	6.0	34	47.7	.093	3	11	>310	0	.0192	49	.314
2.9	6.4	35	60.6	.156	6	11	>310	1	.0391	53	.346
2.5	5.5	35	55.3(2)	.134(2)	2	6	>310	1	.0131	—	—
1.4	7.5	33	54.2	.246	6	14	>310	1	.0549	54	.494
14.3	24.7	61 R_A	61.4	.474	11	48	265	11	.1231	59	.660

can be involved in the fracture process under the imposed stress state. Whether or not a material has the capacity to deform plastically under another stress state should not necessarily have any influence on the value of the stress intensity factor determined under plane strain. Fractures of quenched and tempered 4335 containing high residual aluminum contained both fibrous areas and smooth faceted areas and small shear lips. Appearance of the smooth faceted areas in cast steel fractures indicates the presence of aluminum nitride embrittlement (Fig. 10).

High sulfur plus phosphorus heats of through quenched 4335 composition heats clearly lowered the fracture toughness. K_{Ic} values diminished from 105.4 ksi·in.$^{\frac{1}{2}}$ at 0.019% S and 0.012% P to 47.7 ksi·in.$^{\frac{1}{2}}$ at 0.066% S and 0.066% P. The loss in toughness associated with total S + P content is also reflected in the values of the crack size factor, $(K_{Ic}/y.s.)^2$, the maximum Charpy V-notch energy and the 20% fibrosity fracture appearance transition temperature (FATT$_{20}$).

The relation between K_{Ic} and the sum of the sulfur plus phosphorus content at the intermediate strength levels (152 to 158 ksi yield strengths) of quenched and tempered 4335 is shown in Fig. 11. The value of K_{Ic} continually decreased as the total sulfur and phosphorus content was increased. In addition, the degradation effect appears to be additive. In three of the four heats in which sulfur and phosphorus additions were made, the sulfur and phosphorus contents were increased by approximately equal amounts. Heat No. 39, however, contained relatively low sulfur (0.025%) and high phosphorus (0.046%), yet the fracture toughness of this heat followed the same trend as the remainder of the heats. The degradation effect was the most pronounced upon increasing the total sulfur and phosphorus content from 0.031 to 0.071%. This initial 0.040% increase in total sulfur and phosphorus content resulted in a 38.5 ksi·in.$^{\frac{1}{2}}$ decrease in K_{Ic} (105.4 to 66.9 ksi·in.$^{\frac{1}{2}}$). Further increases in the total sulfur and phosphorus content from 0.071 to 0.132 (a 0.061 increase) only decreased K_{Ic} by 19.2 ksi·in.$^{\frac{1}{2}}$ (from 66.9 to 47.7 ksi·in.$^{\frac{1}{2}}$).

Brittle fractures of high sulfur and phosphorus, quenched and tempered 4335 are indicated by the almost near absence of shear lips. The surfaces had a rough textured appearance with the fracture appearing to follow an interdendritic path (Fig. 10).

Normalized and tempered 9535 heats contained a Widmanstatten ferrite and pearlite structure and exhibited K_{Ic} values of 54.2 and 61.4 ksi·in.$^{\frac{1}{2}}$ at a yield strength of 190 and 89 ksi, respectively. Crack size factors were 0.246 in. for heat No. 13 and 0.474 in. for heat No. 27. The increase in fracture toughness with a decrease in yield strength was expected. A comparison of the fracture toughness data obtained from cast bars measuring 6 x 11 in. cross section (1550 lb heats) of 4335 steel and the 9535 heats indicates that normalizing and tempered 9535 provide lower toughness than through quenched or slack quenched 4335 at the lower strength levels. These 9535 steels had relatively low Charpy V-notch energy values and high fracture transition temperatures. The fractures of these steels were flat with a bright appearance indicating brittle fracture behavior. Small shear lips were formed in the higher toughness specimen (No. 27, Fig. 12) while shear lips were absent in specimen No. 13.

Cast and wrought K_{Ic} data are shown in Fig. 13. This figure contains the K_{Ic} plotted versus yield strength for the data obtained from the literature(12, 22-32) and those obtained in this investigation for through quenched cast 4335 (both nominal composition and high residual aluminum) and normalized and tempered cast 9535. At the higher yield strength levels (about 200 ksi) cast 4335 had K_{Ic} values approximately 30% higher than wrought 4340. Some of this difference may be the result of the higher carbon content of the wrought 4340. Over the 155 to 175 ksi yield strength range, air melted cast 4335 steel had K_{Ic} values that were only 20–30% less than those reported for the vacuum arc remelted HP-9Ni-4Co-25C alloy. At lower yield strength levels (40–75 ksi) cast 4335 provides a higher fracture toughness than a number of wrought steels (A 469 forging, A 470 forging, CrMoV forging, 1045, 4140 and 1144) and the A 356 casting. Over the 75–115 ksi yield strength range, the trend of the cast 9535 data illustrates that the fracture toughness of this alloy compares favorably with the A 470 and Cr-Mo-V forgings and the 1144 steel. Fracture toughness values for the 9535 cast steel, however, were about 25 to 75% less than the A 469 and A 471 forgings.

The highest K_{Ic} values have been reported for maraging steels(22-24). A recent investigation(33) reports K_{Ic} values for air melted and sand cast maraging steel of 95 ksi·in.$^{\frac{1}{2}}$ at a yield strength of 230 ksi and of 118 ksi·in.$^{\frac{1}{2}}$ at a yield strength of 189 ksi. These values are located just slightly below the trend line shown for wrought 18 NiCrMo maraging steel in Fig. 13. The cast maraging steels(33) were specially developed to combine castability with toughness at high strength. A previous investigation(34) reports K_{Ic} values of 68.5 to 80.5 ksi·in.$^{\frac{1}{2}}$ for cast maraging steels that ranged in yield strength from 200 to 22 ksi.

Charpy V-Notch Correlations

Fracture toughness evaluation by plane strain toughness evaluation is complex, time-consuming and costly. Correlations between K_{Ic} and more conventional and economic test procedures are therefore desirable. Correlations with the Charpy V-notch test, where a vast data bank is available would be most attractive.

An example of the temperature/Charpy V-notch impact energy relation is illustrated in Fig. 14 for cast AISI 4335 steels of various heat treatment and

S + P contents. Our studies indicate that room temperature K_{Ic} relates best to the Charpy V-notch energy values at room temperature. A plot of the crack size factor $(K_{Ic}/\sigma_{ys})^2$ versus the ratio of room temperature absorbed energy to the yield strength (CVN/σ_{ys}) is shown in Fig. 15.

A least squares analysis of the data provided the following relationship between K_{Ic} and the Charpy V-notch absorbed energy at room temperature:

$$\left(\frac{K_{Ic}}{\sigma_{ys}}\right)^2 = 2.786 \left(\frac{\text{CVN}}{\sigma_{ys}}\right) + 0.090 \quad . \; . \; . \; (4)$$

The correlation coefficient, R, for this relationship was 0.855 with a standard error of 0.091. This is considered to indicate a good correlation between the two parameters. For a sample size of 17 there is only one chance in 1000 of obtaining $R \geqq 0.693$ by chance. The relationship between room temperature absorbed energy and fracture toughness obtained by Barsom and Rolfe(35) for a variety of steel compositions is also shown in Fig. 15. The Barsom and Rolfe equation has a steeper slope than the equation obtained in the present work indicating a larger value of the crack size factor for a given value of absorbed energy. These differences in slope could result from the specimen size used to determine fracture toughness values in the Barsom and Rolfe work. All of the fracture toughness values were obtained from 1-in.-thick specimens which provided valid K_{Ic} values for only 4 of the 11 steel compositions in the correlation. Higher fracture toughness values would be obtained from those tests in which the thickness was insufficient to produce plane strain conditions. Barsom and Rolfe used room temperature absorbed energy values, but regarded these values as upper shelf values.

The relationship between K_{Ic} values and the room temperature absorbed energy values is empirical in nature. As discussed previously, no fundamental basis exists to relate the values of the two parameters. The small size of the Charpy specimen is only sufficient to develop plane strain in extremely brittle materials and its blunt notch represents only a mild stress concentration compared to the fatigue crack used in fracture toughness specimens. In addition, the absorbed energy value determined in the Charpy impact test represents the total energy to both initiate and propagate a crack, while a fracture toughness test is concerned only with propagation of an existing crack. Nevertheless, the high correlation coefficient obtained from the least squares analysis of the data suggests that some relationship does exist between values of plane strain fracture toughness and Charpy V-notch absorbed energy values measured at room temperature.

Summary and Conclusions

The plane strain fracture toughness of cast steels was measured for the AISI 4335 composition in the quenched and tempered condition in the 75–205 ksi yield strength range and for the AISI 9535 composition in the normalized and tempered condition at yield strength levels of 89 and 109 ksi. The results of this investigation permit the following conclusions:

1. Through quenched and tempered cast AISI 4335 steels exhibited a fracture toughness, K_{Ic}, of 81 to 105 ksi·in.$^{\frac{1}{2}}$ at yield strength levels of 173 to 158 ksi. K_{Ic} decreased with strength as expected. Lower toughness resulted from slack quenching; K_{Ic} values of slack quenched cast AISI 4335 ranged from 84 to 95 ksi·in.$^{\frac{1}{2}}$ at yield strength values of 131 to 126 ksi. Normalized and tempered cast AISI 9535 steels had still lower K_{Ic} values of 54 to 61 ksi·in.$^{\frac{1}{2}}$ at yield strength level of 109 to 89 ksi.

2. A comparison between data obtained in this investigation and data taken from the literature indicated that the fracture toughness of cast steels compared favorably with the fracture toughness of wrought steels. At the higher yield strength levels (about 200 ksi), cast 4335 had K_{Ic} values that were approximately 30% higher than wrought 4340. Over the 158 to 175 ksi yield strength range, the air melted cast 4335 steel had K_{Ic} values that were only 20–30% less than those reported for vacuum arc remelted HP-9Ni-4Co-25C. At the lower strength levels cast 4335 would provide a higher fracture toughness than a number of wrought steels. The fracture toughness of cast 9535 also compared favorably with a number of wrought steels.

3. A good correlation was obtained between room temperature values of K_{Ic} and Charpy V-notch absorbed energy. A least squares analysis of the data indicated the following relationship between these parameters at a correlation coefficient of $R = 0.855$:

$$\left(\frac{K_{Ic}}{\sigma_{ys}}\right)^2 = 2.786 \frac{\text{CVN}}{\sigma_{ys}} + 0.090$$

4. Aluminum nitride embrittlement did not affect the plane strain fracture toughness value of cast 4335 steel. K_{Ic} values ranging from 82.0 to 105.4 ksi·in.$^{\frac{1}{2}}$ were obtained for nominal composition (about 0.020% S and 0.017% P) and aluminum nitride embrittled heats in the 158 to 205 ksi yield strength range. Higher sulfur and phosphorus content markedly lowered the fracture toughness of cast 4335 steel in the 152 to 158 ksi yield strength range. The effect of these elements on K_{Ic} appeared to be additive. Increasing the total sulfur plus phosphorus content from 0.031 to 0.132 decreased the value of K_{Ic} from 105.4 ksi·in.$^{\frac{1}{2}}$ to 47.7 ksi·in.$^{\frac{1}{2}}$. Slack quenching decreased the fracture toughness of cast 4335 steel. The normalized and tempered 9535 cast steel composition provided lower values of plane strain fracture toughness than quenched and tempered 4335 steel at lower strength levels.

REFERENCES

1. J. E. Srawley and J. B. Esgar, "Investigation of Hydrotest Failure of Thiokal Chemical Corporation 260-inch Diameter S1-1 Motor Case", NASA TM X-1194, 1966.
2. Mil. Handbook 5A, Metallic Materials and Elements for Aerospace, Vehicle Structures, February 8, 1966.
3. R. J. Goode, "Evaluating Alloys for Failure-Safe Structures", *Metal Progress*, July, 1967, p. 95.
4. C. F. Tiffany, P. M. Lorenz, and L. R. Hall, "Investigation of Plane-Strain Flaw Growth in Thick Walled Tanks", NASA Cr-54837, February, 1966.
5. E. T. Wessel and T. R. Mager, "Fracture Mechanics Technology as Applied to Thick-Walled Nuclear Pressure Vessels", Westinghouse Research Paper 70-1E7-FMPWR-P9, October 23, 1970.
6. G. Bartholome, M. Miksch, G. Neubrech and G. Vasukis, "Fracture and Safety Analysis of Nuclear Pressure Vessels", Engineering Fracture Mechanics, Vol. 4, 1973, pp. 431–446.
7. H. D. Greenberg and W. G. Clark, "A Fracture Mechanics Approach to the Development of Realistic Acceptance Standards for Heavy-Walled Steel Castings", Metals Engineering Quarterly, ASM, Vol. 31, August, 1969, pp. 30–39.

8. 1972 Appendix G, Section III of ASME Boiler and Pressure Vesel Code.
9. C. Schabtach, E. L. Fagleman, H. W. Rankin and D. H. Winne, "Report of the Investigation of Two Generator Rotor Failures," Trans. ASME, Vol. 78, October 1956, p. 1567.
10. H. D. Emmert, "Investigation of Large Steam Turbine Spindle Failure", Trans. ASME, Vol. 78, October 1956, p. 1547.
11. L. E. Tucker, R. W. Landgraf, and W. R. Brose, "Proposed Technical Report on Fatigue Properties for the SAE Handbook", Paper No. 740279, Automotive Engineering Congress, Detroit, Michigan, February 1974.
12. A. K. Shoemaker and S. T. Rolfe, "The Static and Dynamic Low Temperature Crack Toughness Performance of Seven Structural Steels", Engineering Fracture Mechanics, Vol. 2, 1971, pp. 319–339.
13. J. S. Pascover, et al, "The Application of Fracture Toughness Testing to the Development of a Family of Alloy Steels", ASTM STP 381, 1964, p. 310.
14. Second Report of ASTM Special Committee on Fracture Testing of High-Strength Metallic Materials, "The Slow Growth and Rapid Propagation of Cracks", Materials Research & Standards, Vol. 1, No. 5, May 1961, pp. 389–393.
15. C. F. Tiffany and J. N. Masters, "Applied Fracture Mechanics", ASTM, STP 381, 1964, p. 249.
16. J. A. Kies, et al, "Fracture Testing of Weldments", ASTM, STP 381, 1964, p. 328.
17. A. J. Birkle, R. P. Wei, G. E. Pellissier, "Analysis of Plane Strain Fracture in a Series of 0.45C-Ni-Cr-Mo Steels with Different Sulfur Contents", Trans, ASM, Vol. 59, 1966, pp. 981–990.
18. E. F. Kula and A. A. Anctil, "Tempered Martensite Embrittlement and Fracture Toughness in SAE 4340 Steel", Journal of Materials, Vol. 4, No. 4, December 1969, pp. 817–841.
19. J. J. Hauser and M. G. H. Wells, "Inclusions in High Strength Steels—Their Dependence on Processing Variables and Their Effect on Engineering Properties", Technical Report AFML-TR-68-222, August 1968.
20. P. C. Paris, "The Fracture Mechanics Approach to Fatigue," Proc. Tenth Sagamore Army Materials Research Conference, August, 1963, Syracuse University Press, (1964).
21. A. W. Gunderson, "Fracture Mechanics Tests and Analyses of the AEDC APTU Storage Vessel Material", Technical Report AFML-TR-74-133, October, 1974. Air Force Materials Laboratory, Air Force Systems Command, Wright–Patterson Air Force Base, Ohio 45432.
22. E. T. Wessel and W. G. Clark, Jr., "Fracture Prevention Procedure for Heavy-Section Components", Westinghouse Scientific Paper 70-1E7-FMPWR-P2, January 14, 1970.
23. W. K. Wilson, W. G. Clark, and E. T. Wessel, "Fracture Mechanics Technology for Combined Loading of Low to Intermediate Strength Metals", Technical Report No. 102276, Contract DAACO7-C-4021, November 18 ,1968.
24. E. T. Wessel, "State of the Art of the WOL Specimen for K_{Ic} Fracture Toughness Testing", Westinghouse Research Report 67-1D6-BTLFR-R1, March 22, 1967.
25. I. L. Purdy and J. Shewchuk, "The Effect of Specimen Type and Preparation on Fracture Toughness Measurements", Journal of Materials, Vol. 7, No. 1, March 1972, pp. 38–42.

26. D. M. Fisher and A. J. Repko, "Plane Strain Fracture Toughness Tests on 2.4 and 3.9-inch-thick Maraging Steel Specimens at Various Yield Strength Levels", Journal of Materials, Vol. 7, No. 2, June 1972, pp. 167–177.

27. C. E. Fedderson, C. E. Moon and W. S. Hyler, "Crack Behavior in D6AS Steel", MCIC Report MCIC-72-04, Battelle Memorial Institute, January 1972.

28. P. R. V. Evans, M. A. Eilkins and N. B. Owen, "Effect of Purity on the Toughness of Low Alloy, High Strength Steel", J. Iron and Steel Institute, Vol. 210, Part 3, March 1972, pp. 200–203.

29. E. A. Steigerwald, "Plane Strain Fracture Toughness for Handbook Presentation", AFML TR-67-187, July 1967.

30. B. L. Jones, Royal Armament Research and Development Establishment, personal communication to J. F. Wallace.

31. R. E. Jones, "Tensile, Fracture Toughness and Crack Growth Properties of a Roll Extruded HP-9Ni-4Co-25C Steel Alloy", AFML-TR-71-250, December 1971.

32. E. T. Wessel, W. G. Clark and W. K. Wilson, "Engineering Methods for Design and Selection of Materials Against Fracture", Contract No. DA-30-069-AMC-602, June 24, 1966.

33. S. Floreen, "New Cast Air Meltable High Strength Steels", January, 1975, Submitted for Publication in ASM Metals Engineering Quarterly.

34. W. J. Jackson, et al, "High Strength Cast Steels", The British Foundryman, August, 1972, p. 286.

35. J. M. Barsom and S. T. Rolfe, "Correlation Between Charpy V-Notch Test Results in the Transition-Temperature Range", Impact Testing of Metals, ASTM STP 466, 1970, pp. 281–302.

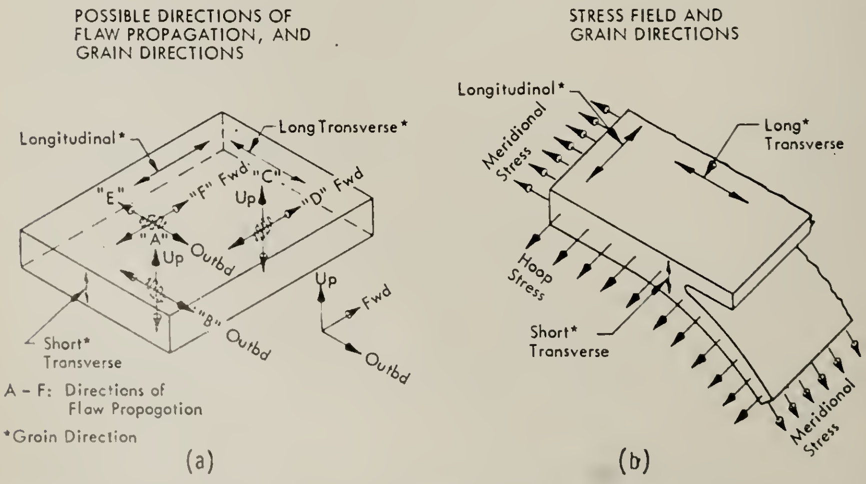


Fig. 1—Stress field, grain directions, and possible directions of flaw propagation (15).

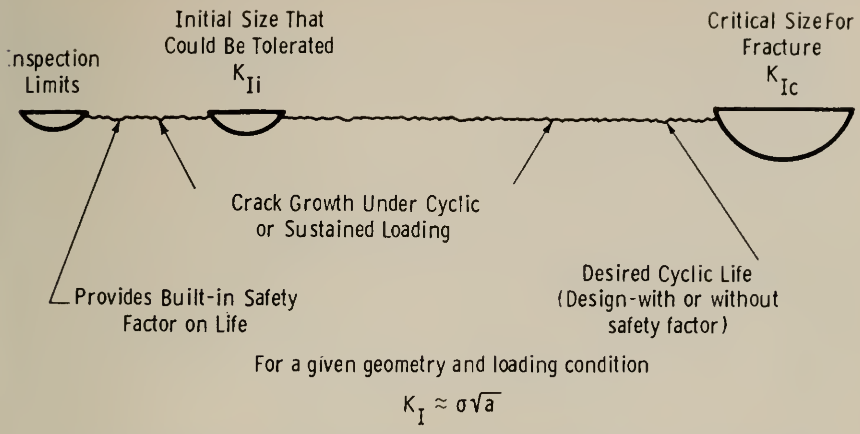

Inspection Limits
Initial Size That Could Be Tolerated K_{Ii}
Critical Size For Fracture K_{Ic}
Crack Growth Under Cyclic or Sustained Loading
Provides Built-in Safety Factor on Life
Desired Cyclic Life (Design-with or without safety factor)
For a given geometry and loading condition
$K_I \approx \sigma\sqrt{a}$

Fig. 2—Schematic: various defect sizes of concern in fracture mechanics analysis (5).

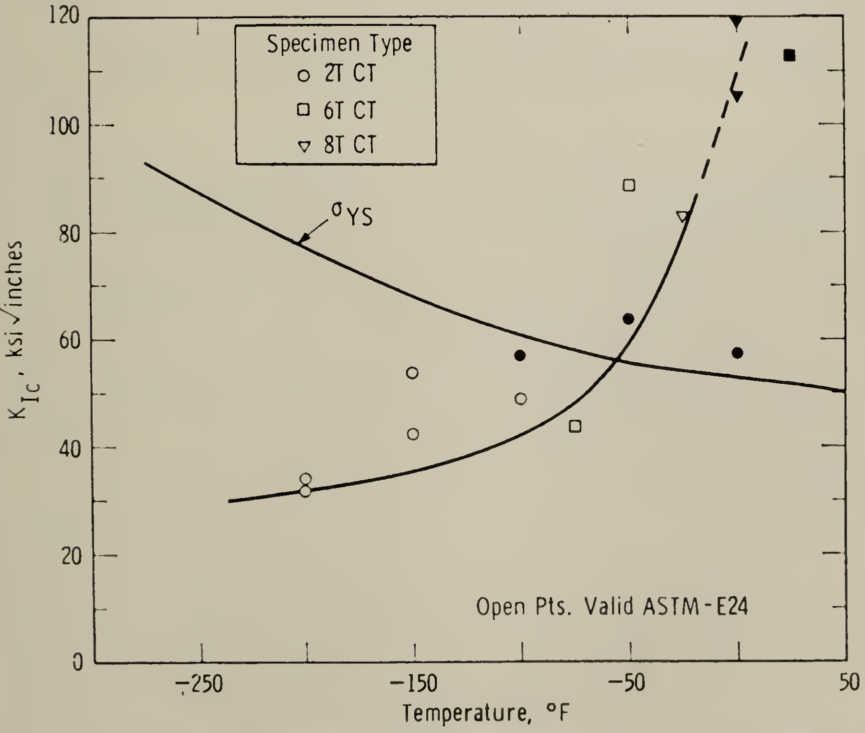


Fig. 3—Temperature dependence of yield strength and K_{Ic} fracture toughness for an A 216 (WCC Grade) steel casting (7).

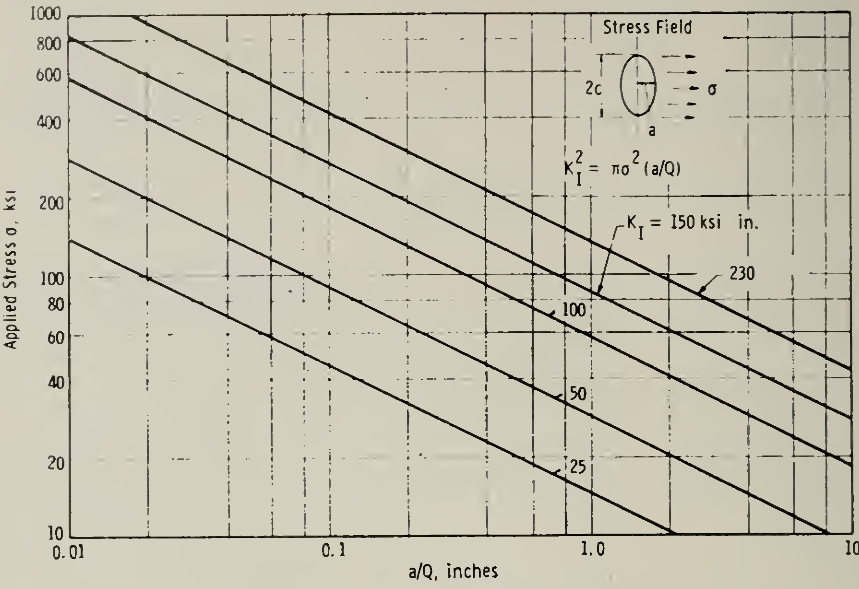


Fig. 4—Graphical solutions for an internal disc-shape flaw, embedded in a large body (tension loading) (7).

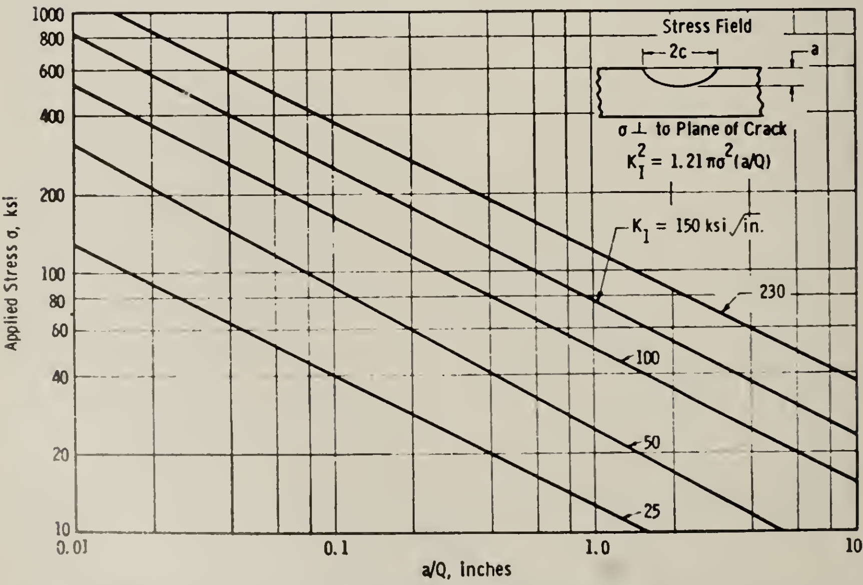


Fig. 5—Graphical solution for an elliptical surface crack (tension loading) (7).

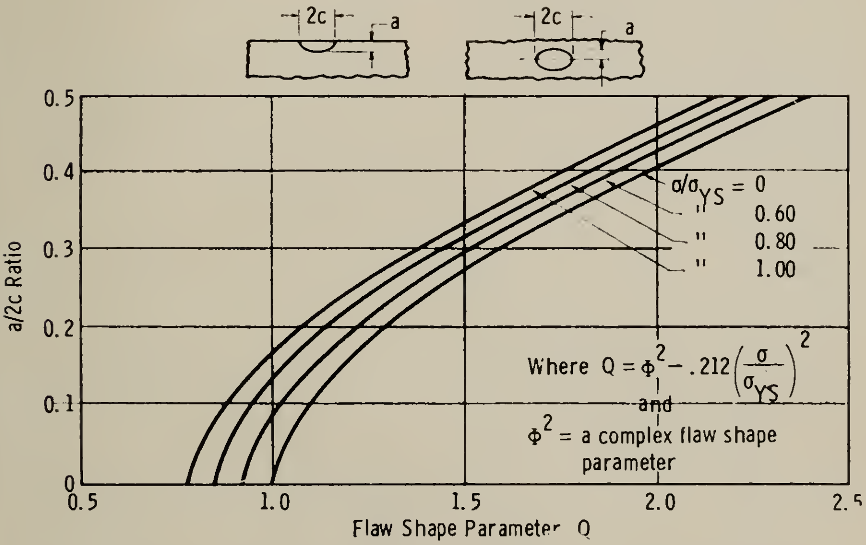


Fig. 6—Flaw shape parameter curves for surface and internal cracks (7).

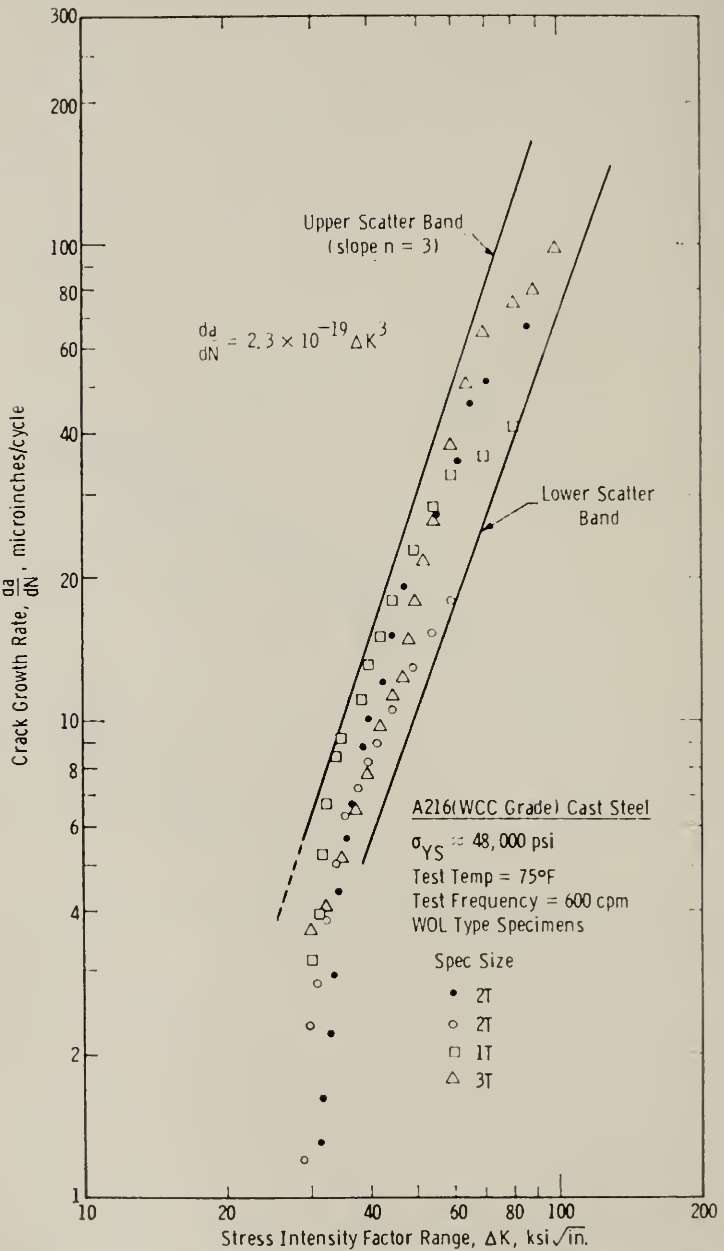
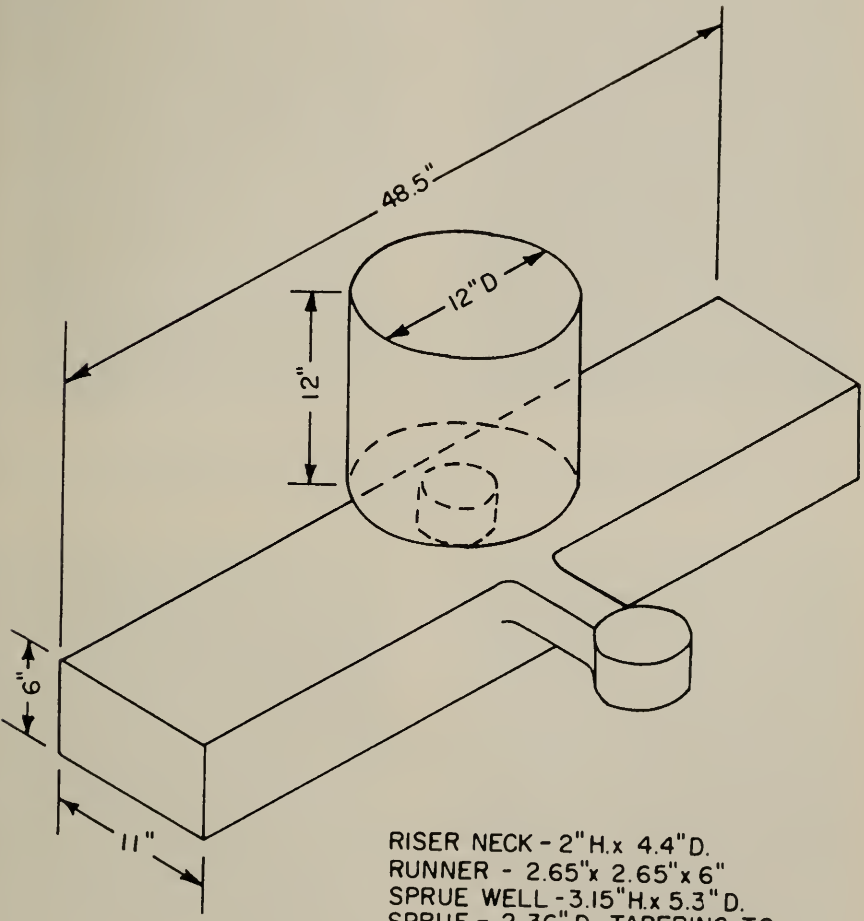


Fig. 7—Fatigue crack growth rate as a function of Δk for A 216 (WCC Grade) cast steel (7).



RISER NECK - 2" H.x 4.4" D.
RUNNER - 2.65"x 2.65"x 6"
SPRUE WELL - 3.15" H.x 5.3" D.
SPRUE - 2.36" D. TAPERING TO
1.3" D. x 6" LENGTH

Fig. 8a—Casting poured from 1550-lb heats (spruce and pouring basin are omitted for clarity).

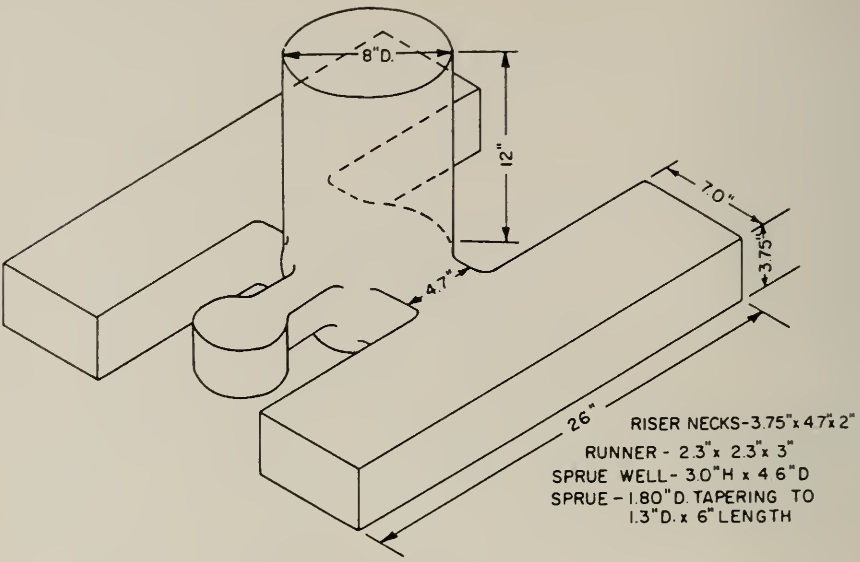

8"D.
12"
7.0"
3.75"
4.7"
26"
RISER NECKS-3.75"x 4.7"x 2"
RUNNER - 2.3"x 2.3"x 3"
SPRUE WELL- 3.0"H x 4.6"D
SPRUE - 1.80"D. TAPERING TO
1.3"D. x 6" LENGTH

Fig. 8b—Casting poured from 750-lb heats (spruce and pouring basin are omitted for clarity).

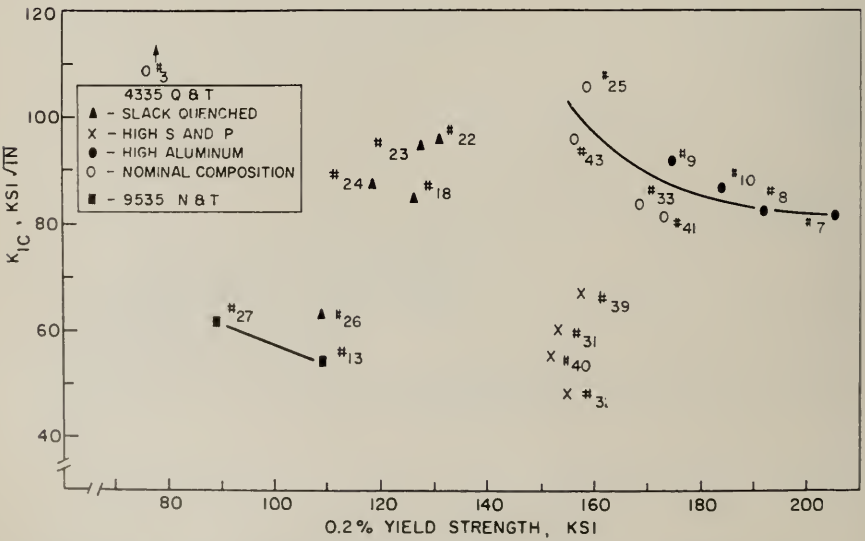
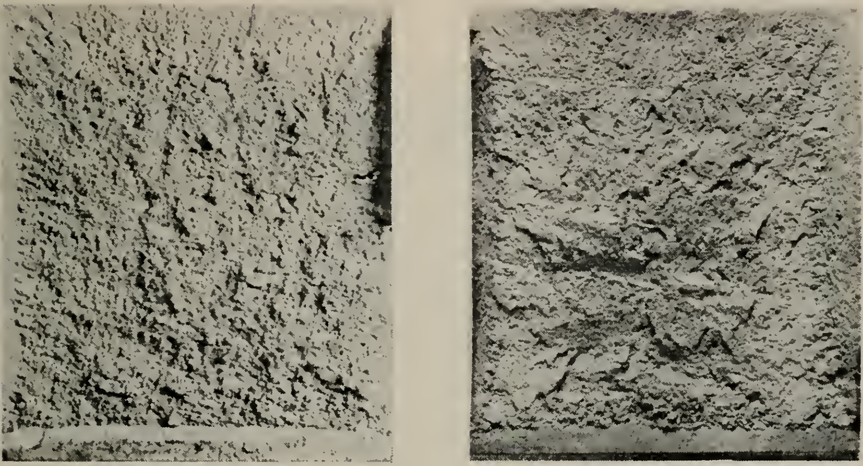
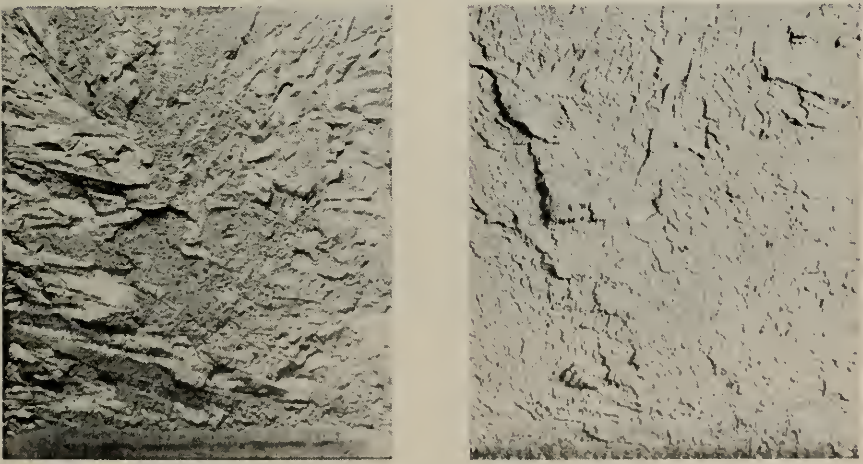


Fig. 9—Plane strain fracture toughness, K_{Ic} at various yield strength levels of cast 4335 and cast 9535 steels.



Heat No. 25, through quenched
Y.S. = 158.5 ksi
$K_{Ic} = 105.4$ *ksi • in.*$^{1/2}$

Heat No. 23, slack quenched
Y.S. = 127.6 ksi
$K_{Ic} = 94.7$ *ksi • in.*$^{1/2}$



Heat No. 9A, high aluminum
Y.S. = 174.6 ksi
$K_{Ic} = 92.1$ *ksi • in.*$^{1/2}$

Heat No. 32, high S + P
Y.S. = 155.9 ksi
$K_{Ic} = 47.7$ *ksi • in.*$^{1/2}$

Fig. 10—Representative fracture appearances of 4335 cast steel, 3-in.-thick notch bend specimens.

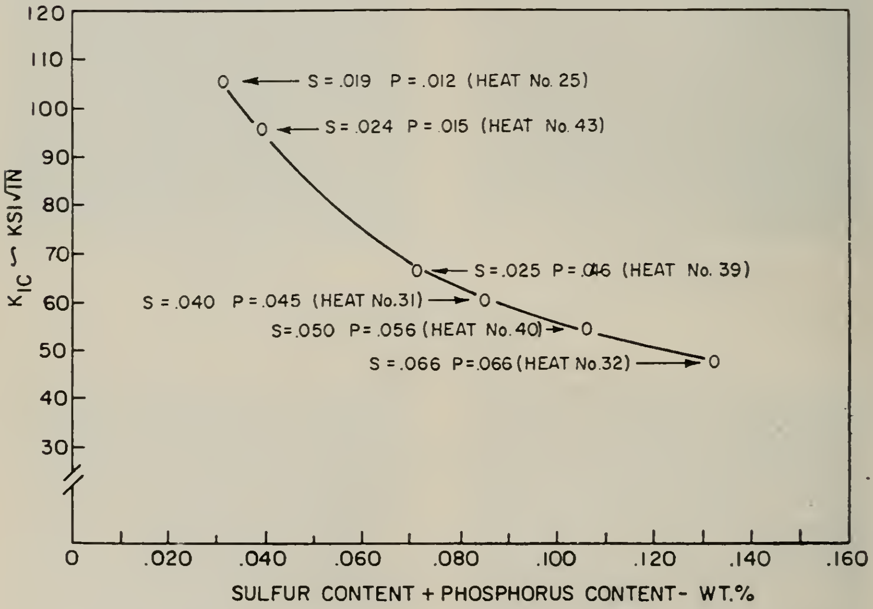
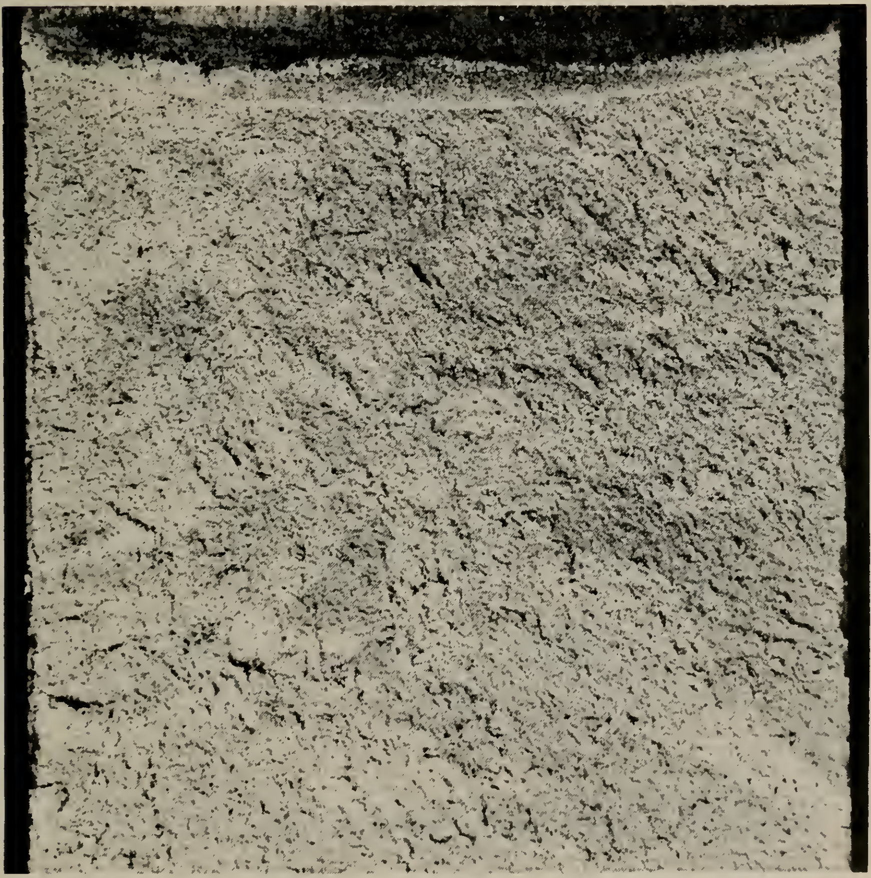


Fig. 11—Effect of sulfur and phosphorus content on K_{Ic} in 4334 cast steel in the 151.6 to 158.5 ksi yield strength range.



Heat No. 27
Y.S. $= 89.2$
$K_{Ic} = 61.4$ *ksi • in.½*

Fig. 12—Representative fracture appearance of 9535 cast steel, 5-in.-thick notch bend specimen.

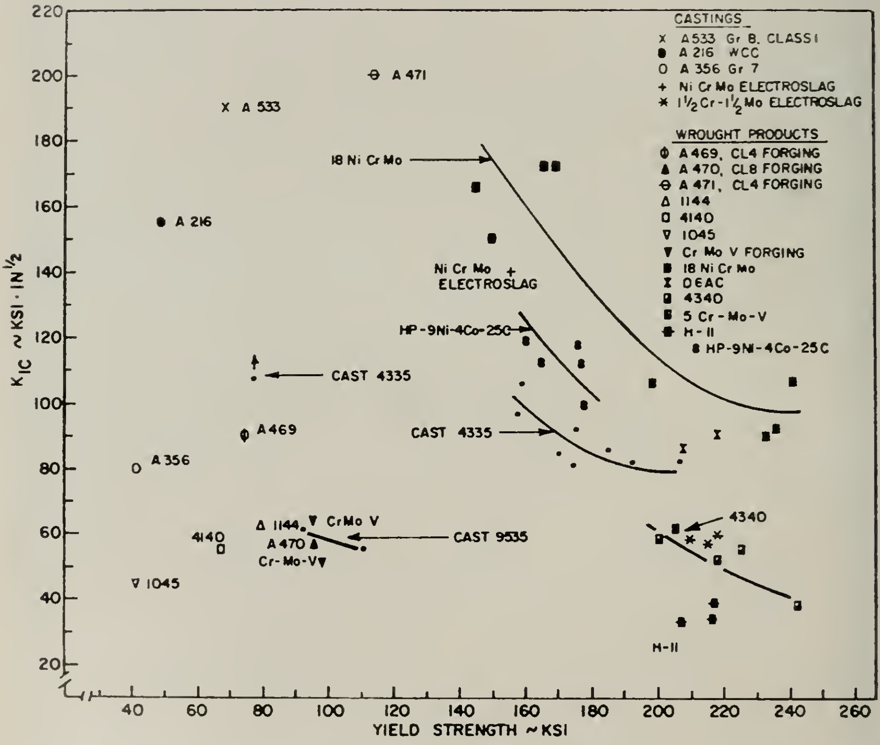


Fig. 13—Plane strain fracture toughness of cast 4335 and cast 9535 compared to other steels.

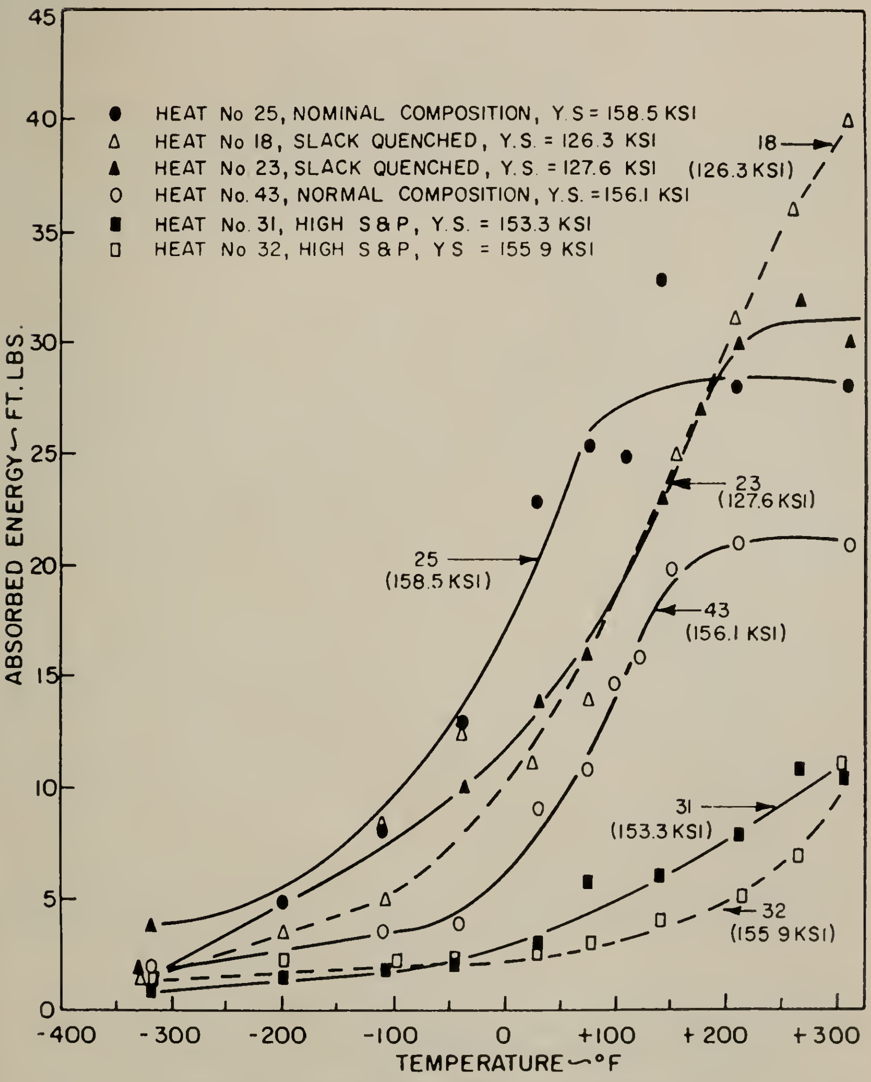


Fig. 14—Comparison of the effects of high sulfur.

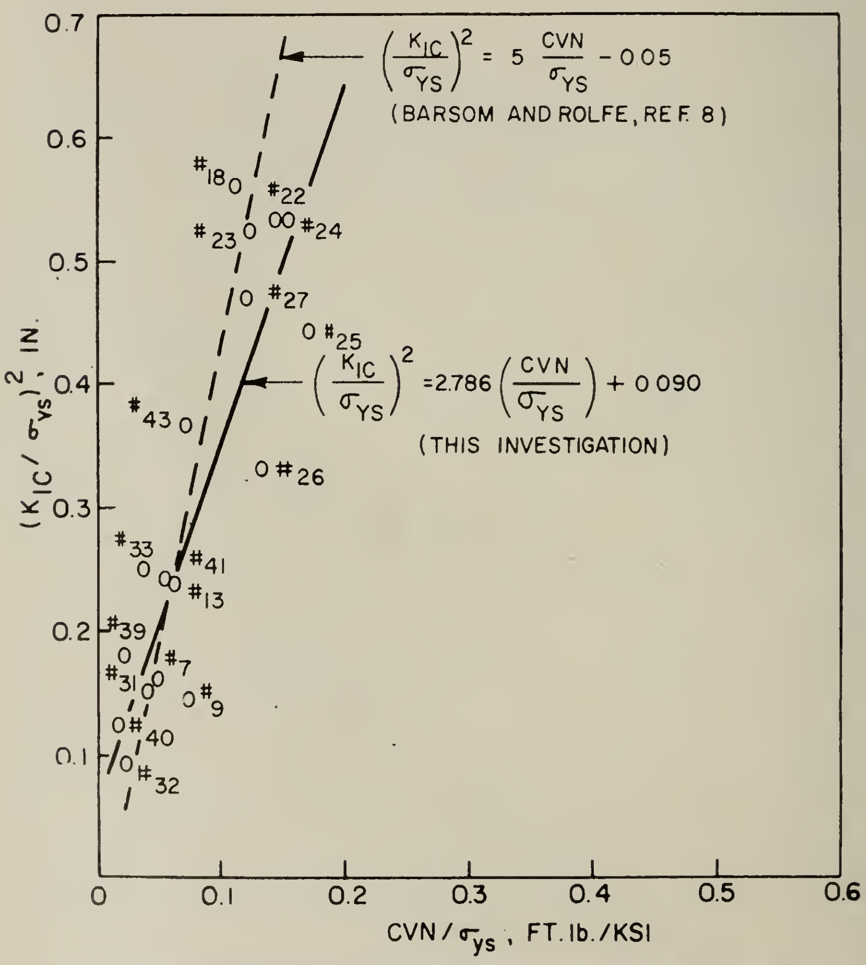


Fig. 15—Relationship between room temperature values of K_{Ic} and Charpy V-notch absorbed energy, CVN (QT 4335 and NT 9535 steel).

Truck Hunting—A Cause and Effect of Component Wear in Freight Car Trucks

76–653–18

By L. A. McLEAN
Chief of Equipment Engineering
Seaboard Coast Line Railroad

It might be appropriate to begin by explaining just what we mean by truck hunting, for those not acquainted with the term. Truck hunting may be defined as a condition where freight car trucks experience sustained lateral oscillations during which the wheel flanges surge from one rail to the other and is characterized by violent impacts that impose severe contact loading on truck and track structures.

Let me also explain how we on SCL became involved in this subject of truck wear and its causes. Three years ago we never considered truck or centerplate wear on SCL as being a particular problem—center plate breakage, yes, but not wear! In fact, as a member of the AAR Car Construction Committee, I once voiced my objection to a proposal to require wear rings in truck bolster bowls on 70-ton cars.

Shortly thereafter, however, an incident occurred which changed my thinking, and this is what happened. One night a freight train was running about 60 mph on our main line between Rocky Mount, N. C., and Florence, S. C., when the crew observed sparks and fire emitting from under a car in their train. When the train was stopped, it was found that a truck had started to come out from under a box car and only the wheels contacting the body bolster kept it in position.

An examination of the trucks on the next day disclosed that the 1-inch-thick rim of the bolster bowls had completely worn through, permitting the truck to disengage from the car. Additionally, the center plates were reduced in diameter longitudinally about 1½ inches. The roller-bearing adapters had worn away ⅞ inch on the surface which contacts the side frame. In the side frame pedestals where contact is made with the adapters, wear was as much as ¼-inch deep. The wheels were slightly tread worn hollow. Also, the coupler carrier wear plates and coupler shanks were severely worn. This car was less than five years old.

Other cars in the same series were inspected and found to be in similarly poor condition. The question of what caused this series of cars to wear out so quickly prompted us to bring in the car builder to discuss the problem and review the design. After all, didn't we learn 10 years ago that cars prone to rock-and-roll are related to certain physical dimensions?

Together with the car builder, we watched these cars operate in a train from a caboose platform. From this it was obvious that truck hunting was accelerating the wear on these cars. Since this baffling problem had no obvious solution, we agreed to conduct sufficient road tests, isolating the effect of one component at a time. We started with a truck which was equivalent to new conditions and kept changing one item at a time until we accumulated the effect of each individual component. Complete instrumentation and motion pictures were planned.

We found that the most prominent factor affecting hunting is the contour of the wheel tread. Only a small amount of wear quickly reduces the critical speed

---

Note: Discussion open until October 15, 1975.

at which hunting begins. Incidentally, the thousands of feet of film we made was originally intended only to study in conjunction with interpreting the oscillograph recordings of the transducers and accelerometers. However, the film was so enlightening that we later decided to put together excerpts of each test and the results you will see in a moment.

The track on which we conducted our test runs consisted of 132-lb welded rail laid new in 1969 on 7- x 14-inch double-shoulder tie plates. There was a full ballast section with at least 6 inches or more extending out beyond the ends of the ties and tapering down therefrom to the roadbed section. The track was on sound ties and had good line, surface and gage. The track was on tangent in the area traversed.

We believe that mentioning the track is very significant because, unlike the rock-and-roll problem, it is recognized that the better the track, the greater is the likelihood of sustained oscillation after the car reaches its critical speed. So this is one problem that the mechanical people cannot blame on the roadway people.

In the movie you will see a test using a friction bearing truck with its normal free lateral to compare to the roller-bearing truck with no lateral. The most amazing discovery was the wheel lifts that you will clearly see. I don't believe that truck hunting alone causes derailments, but it can certainly stimulate your imagination of what can happen if a hunting truck passes over a track imperfection at just the right time.

In looking at these scenes, please bear in mind that the cameras were rigidly fixed to the car body and you will not readily sense the violence experienced had you been riding in the car during the test. However, if you will pay close attention to the rails, you can see them begin to move rapidly back and forth.

May we now have the film.

(The film was shown.)

Now that you have seen what is happening under our "modern" freight cars, it logically comes to mind the questions of what causes this phenomenon and what can be done about it.

I certainly wish I had the answers for you today, but it is a rather complex problem relating to the contact angle between the wheel and the rail, the mass of the wheel set and supported load, rotational speed of wheelset, springing, rigidity of truck, torsional moment of inertia of wheels, etc. The whole problem has now been given a rather high priority by the AAR to find a solution, and although these tests were made over two years ago, we have yet to see a readily applied solution for the problem.

When the dust settled on our test work, we began to assess the results. Throughout this work, we had a recurring thought of why this has not been happening in the past. What has suddenly changed?

One thing we learned was that trucks don't hunt on wet rail. Could it be that our rail was previously "wet"? Perhaps so, when you begin to realize that we are depositing less and less car oil out of journal boxes as roller bearings become in greater useage. How about lateral? You saw that the rigid lateral in the roller-bearing truck induced hunting far earlier than in a truck with lateral.

Could changes in braking be a factor? We think that this has had a definite effect on bringing about conditions that rapidly lower the critical speed for hunting. Let us explore this for a moment. Braking levels have been gradually raised over the past ten years. Also, the introduction of composition brake shoes has increased the retardation rate during higher speeds because of their characteristically higher coefficient of friction. It follows, then, that the wheel wear must increase slightly, rapidly eliminating the 1 in 20 contour. It also increases the pressure between the center plate and bolster bowl.

Additionally, close examination of the motion pictures made during the tests showed that the trucks had greater wheel lifts at diagonal corners of the truck than at the corresponding corners. We studied the brake beams and found that only the diagonal ends of the beams in each truck were wearing from hard lateral contact with the brake beam wear plates in the side frames. From this we deduced that the beams were being forced laterally by the braking forces.

The trucks tend to steer to a direction opposite to that which you would expect from the top rod action. We confirmed this by noting that the wheel flanges were more heavily worn on all cars in this series at the locations shown striking the rails.

We further investigated why the beams acted as they did and got our clue to this mystery from review of many static brake shoe force tests made on new cars at the car builders plants and in our shops. We saw that the brake forces were consistently unequal on shoes of the same beams. However, when we compared the forces on diagonal shoes in each truck, they were usually quite similar. A simple moment calculation shows that if the shoe forces are not equal and the lever force is being applied in the center of the beam, then the truck lever must be applying a moment in the order of about 6000 in-lb. A more detailed resolution of forces would show that this causes the lateral shift of the beams.

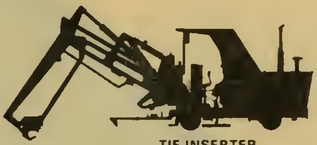
The next logical question is what causes the moment. We believe it is the familiar bend in the truck lever. Heretofore this bend was not as great. But with the much lower lever ratio required with composition shoes, our levers had to be bent more to permit greater clearance for the top rod between the truck bolster and the body bolster that results from the greater lever angularity. Thus, with increased lever angularity goes greater twisting of the lever in the brake beam strut; hence, parallelogram trucks.

As I stated earlier, this whole problem of truck wear and its causes is quite complex, but I hope I have given you some food for thought on this rather costly problem. As railroaders, we need to seek real solutions to these matters rather than continually adding wear plates every time a point of wear develops. We also need to avoid a proliferation of gimmicks or crutches on our trucks, as appeared with the advent of the rock-and-roll problem. Hopefully, the fundamental underlying principles causing this wear phenomenon will be discovered by the heavy research now being undertaken by the AAR and the Federally funded Truck Design Optimization Project on Southern Pacific. With this information made available to our suppliers, we would hope that they would then turn loose their best efforts and imagination to produce real solutions for our industry.

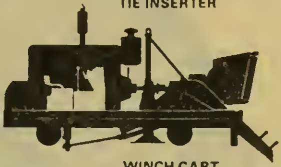
Gentlemen, thank you for giving me this honor of addressing you today.

LORAM

Modern Maintenance
of Way Equipment
with an **established
track record . . .**



TIE INSERTER

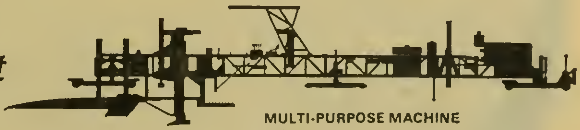


WINCH CART

SHOULDER BALLAST CLEANER

*. . . designed
to do the job
easier, quicker
and at less cost
— with your
men or
ours!*

AUTOSLED



MULTI-PURPOSE MACHINE

AUTOTRACK WITH PLOW AND SLED

THE ANSWER TO YOUR 1975 TRACK REHABILITATION PROGRAM

MEMBER RPI RAILWAY PROGRESS INSTITUTE

LORAM RAILWAY MAINTENANCE EQUIPMENT FOR:

• Shoulder Ballast Cleaning • Raising Track • Resurfacing • Reballasting • Replacing Ties • Undercutting • Ballast Cleaning • Rail Grinding Single or Multiple track—Mainline or Yard tracks

CONTRACT, SALE or LEASE

FOR FULL DETAILS,
OR SHOWING OF
OPERATING FILMS,
WRITE OR CALL TODAY

LORAM MAINTENANCE OF WAY, INC.
3900 Arrowhead Drive • Hamel, MN 55340 U.S.A.
PHONE: (612) 478-6014 • TELEX: 29-0391; Cable, LORAM

MEMBER
RPI
RAILWAY
PROGRESS
INSTITUTE

We've a lot going for you.

We call it "The Big Green," and it's all go. For you.

It's what we put into every one of our railway products to give you the big return you want and need, to meet required standards on your roads.

Our anchors, rail joints, heaters, rail and flange lubricators, and renewal insulation give you the edge in every major investment consideration.

They're built to give you longer, trouble-free performance.

They're built for fast and easy installation.

They're built to save manhours, reduce downtime, keep your trains rolling.

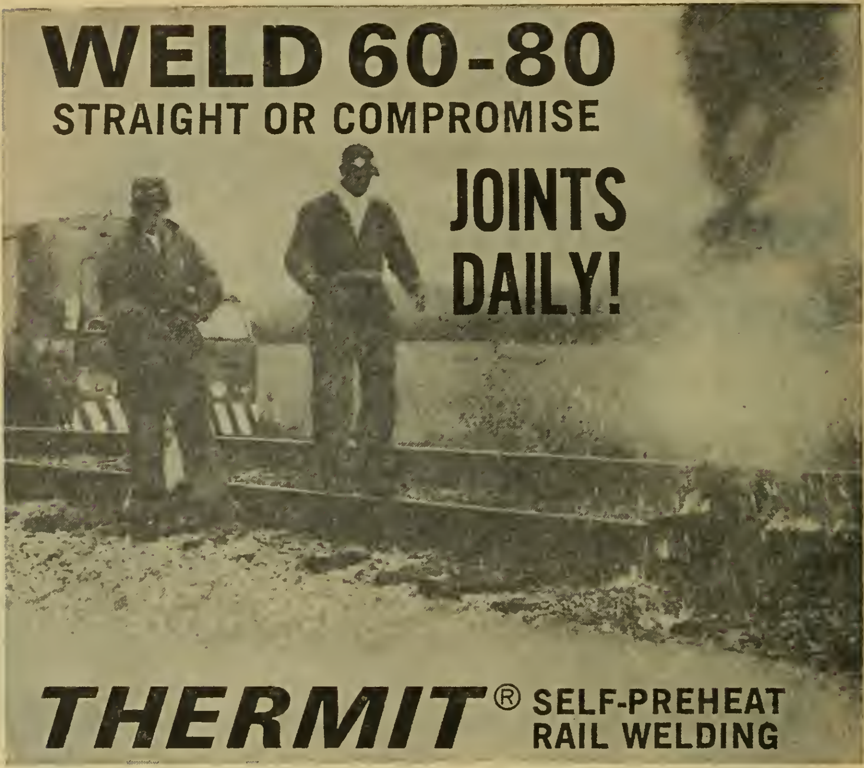
That's where the real savings dollars are. That's where the big return is. Has been. Always will be.

That's why you should talk to your Portec man before you invest in rail anchors, joints, heaters or rail and flange lubricators, and renewal insulation.

The big green. It's as close as your phone.

RAILWAY PRODUCTS DIVISION
The better product producing people.

PORTEC inc.
300 Windsor Drive • Oak Brook, Illinois 60521
(312) 325-6300 • TWX No. 910-651-0212



THE MODERN IN-TRACK METHOD

- AUTOMATIC, **ERROR-FREE** PRE-HEATING AND TAPPING OF WELD METALS
- EASY, **COLD** REMOVAL OF RISERS
- MINIMUM GRINDING
- NO EQUIPMENT TO PURCHASE OR LEASE

FREE COMPLETE THERMIT RAIL WELDING DETAILS **PLUS** JOB-SITE DEMONSTRATIONS.

WRITE OR CALL

THERMIT®

THERMEX METALLURGICAL, INC.
LAKEHURST, N. J. 08733 • (201) 657-5781
SALES OFFICES IN MAJOR CITIES

Channeloc®

Cliploc®

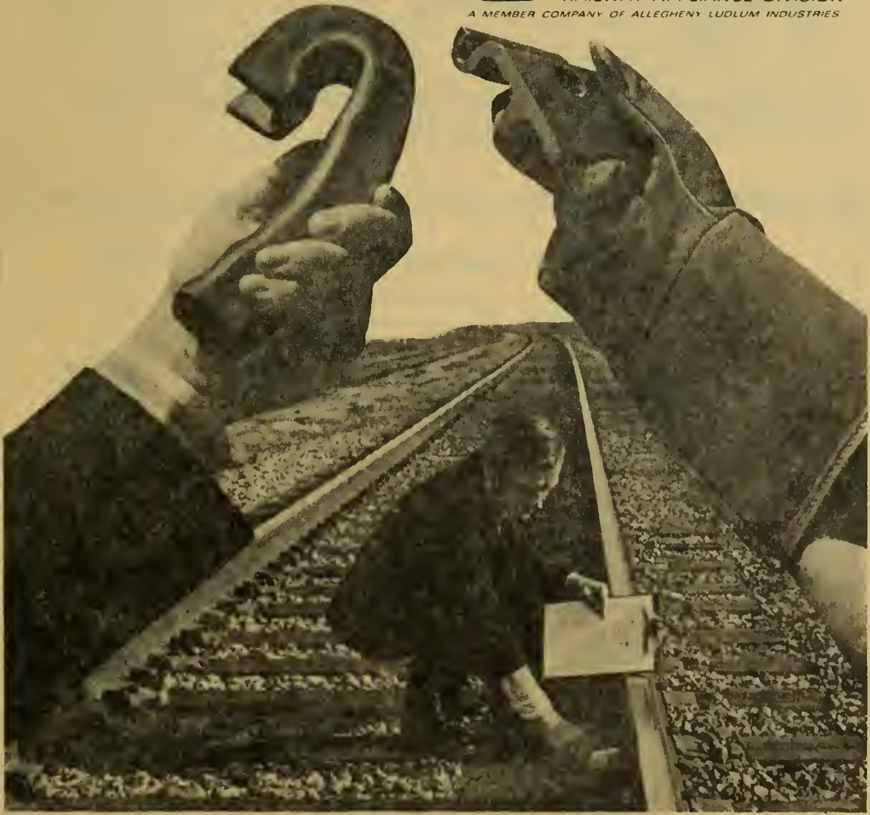
Two for the road ...and then some!

Massive, unique channel shape provides tremendous gripping power. Its great tensile strength adds years to service life . . . and saves replacement costs. Channeloc is applied easily and quickly with minimum ballast disturbance . . . and can be reapplied.

Cliploc® . . . designed, tested and proven for modern concrete tie installations. Choose from standard Cliploc or insulated Cliploc with permanent fiberglass-reinforced epoxy for 100% insulation.

To assure continued quality control, True Temper maintains a Field Service Department. These field engineers spot-check rail anchor applications and return at specified intervals to check in-service durability.

TRUE TEMPER®
RAILWAY APPLIANCE DIVISION
A MEMBER COMPANY OF ALLEGHENY LUDLUM INDUSTRIES



Channeloc is protected by U S Patent Numbers 3,102,690 — 3,118,327 — 3,159,198. Cliploc is protected by U S. Patent Number 3,477,642.

A tradition of service . . .

- Water Treatment Chemicals Protecting Diesel Cooling Systems and Steam Generators
- Fuel Oil Additives
- Pollution Control Chemicals and Consulting Services

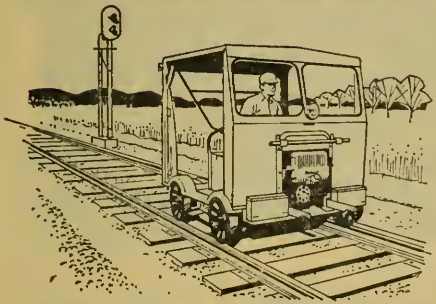
NALCO CHEMICAL COMPANY
2901 BUTTERFIELD ROAD • OAK BROOK, ILLINOIS 60521

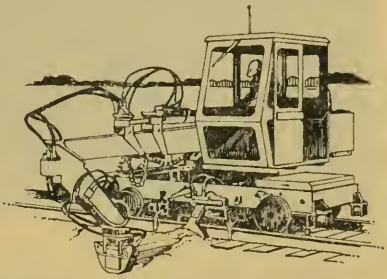
NALCO Trademarks of Nalco Chemical Company

NALCO

Fairmont

RAILWAY MOTOR CARS
AND WORK EQUIPMENT



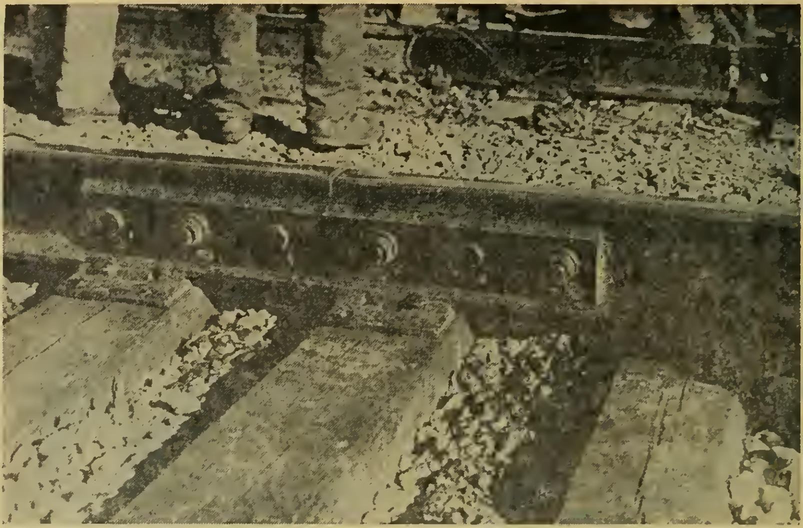


- INSPECTION MOTOR CARS
- SECTION MOTOR CARS
- GANG MOTOR CARS
- PUSH CARS AND TRAILERS
- HY-RAIL EQUIPMENT
- BALLAST MAINTENANCE CARS
- WEED MOWERS
- MOBILE CRANES
- TOW TRACTORS
- RAIL GRINDERS
- DERRICK CARS
- HYDRAULIC POWER TOOLS
- TRACK LINERS
- TRACK LINING LIGHT
- SPIKE DRIVERS
- TIE REMOVERS
- TIE HANDLERS
- RAIL LIFTERS
- TIE SHEARS
- TIE BED SCARIFIERS
- SPIKE PULLERS
- TIE PLUG INSERTERS
- OIL SPRAYERS
- TIE SPRAYERS
- TIE INSERTERS

Performance ON THE JOB COUNTS

THESE UNITS ARE ACTUATED EITHER COMPLETELY
OR PARTIALLY BY HYDRAULIC POWER

FAIRMONT RAILWAY MOTORS, INC., FAIRMONT, MINNESOTA 56031



The Allegheny Insulated Rail Joint-

Designed to withstand the heaviest traffic in welded rail

This modern joint cements rail ends in position and thereafter resists all forces imposed by temperature and simultaneous forces of live loads to move them.

This joint makes welded rail truly continuous. It promises you years of service without maintenance costs. It reduces rail and wheel batter to a previously unknown minimum. It employs the safety of steel splice bars. It can be assembled in the shop or field. It has been tested in service and AAR laboratories. It saves you lots of money.

Allegheny Drop Forge Company

Subsidiary of Tasa Corporation

2707 Preble Avenue • Pittsburgh, Pa. 15233

Nordberg railway equipment.

Saves time and money all along the line.

SELF-PROPELLED ADZER
HYDRA-SPIKER
LINE INDICATOR
PLATE PLACER
POWER JACK
RAIL DRILL
RAIL GANG SPIKER
RAIL GRINDERS
ONE MAN SCARIFIER AND INSERTER
SPIKE HAMMER
SPIKE PULLER
SPIKE STRAIGHTENER
SURF-RAIL GRINDER
SWITCHLINER
TRACK INSPECTOR
TIE DRILL
TIE SPACER
TRACKLINER
DUN-RITE GAGER
X-LEVEL INDICATOR

Right of way maintenance and construction is a tough job, and getting tougher. Nordberg railway equipment is precision engineered to keep things rolling—to get the job done on time, at low cost. Write Rexnord Railway Equipment Division, Box 383, Milwaukee, Wisconsin 53201.

Rexnord

RAILROAD TRACKS
designed, constructed
and completely maintained

**ROBT. L. DEPRIZIO
& ASSOCIATES INC.**

RAILROAD CONSTRUCTION

10625 FRANKLIN AVE.
FRANKLIN PARK

455-4400

Not Associated With V. N. Deprizio Construction Company

KERITE CABLE

For dependability in actual use, no other cable matches Kerite. We believe you will be impressed by the evidence.

MEMBER RPI

THE KERITE COMPANY

PRINCIPAL OFFICES: Boston; Chicago; New York; Philadelphia; San Francisco; and Seymour, Connecticut • Sales Representation throughout the United States. A subsidiary of Harvey Hubbell Incorporated.

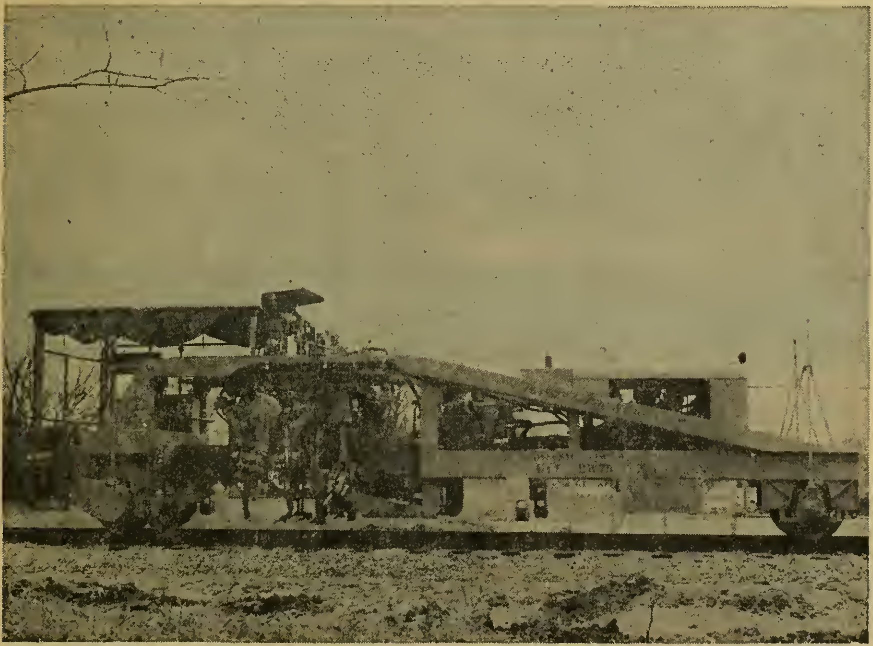
DAYS KERITE

it's the **KERITE** *insulation that makes the difference*

SWITCH TAMPERS FOR ALL YOUR JOBS

UNIVERSAL UYT-2W75 YARD, SWITCH & SPOT TAMPER

This versatile tamper is a new addition to the popular Plasser Universal line. Even though the UYT 2W75 has a lower original cost, it is equipped with two of the exclusive Plasser four-tool tamping heads with individually tiltable tamping arms, which insures the tamping of every tie through switches and turnouts without the use of outside or ground jacks.



This Universal UYT 2W75 tamper is particularly adaptable for yard work where it has proven itself as a money saver. The reasonable price plus its ability to do a fine job tamping switches and doing spot work suggest yard assignment. It can be equipped with automatic lifting and leveling equipment as well as automatic lifting correction with cross level indicator. You should see one of these tampers in service and we will be pleased to make the necessary arrangements for you to do so at your convenience. You will be convinced that it is a superior machine.

PLASSER AMERICAN CORPORATION

PLASSER FOR PERFORMANCE

GENERAL OFFICES & PLANT
2001 MYERS ROAD
CHESAPEAKE, VIRGINIA 23324

EXPERIENCED SPECIALISTS IN THE REPAIRS OF.... RAILROAD STRUCTURES

Turzillo CORPORATION TM

FOUNDATIONS, UNDERPINNING AND INVESTIGATIONS

AUGERCAST® * Piles — placed without vibration

- For new foundations and underpinning
- Retaining wall piles. Low headroom piles
- Tie-back anchoring system for excavations
- Tension piles and anchors

PRESSURE GROUTING

- BAGPIPE® * Groutainer™ inflatable forming system
- Soil stabilization for arresting settlement of structures
- FIRM-UP® chemical grouting for consolidating soils
- Consolidating masonry bridge abutments and piers

CONCRETE AND MASONRY STRUCTURAL REPAIRS

- Bridges, dams, power plants and dry docks
- Scour repairs
- Tunnel lining repairs
- Repairs to precast, concrete, wood and steel piles

PREPLACED AGGREGATE CONCRETE (PAC)

- Cofferdam seals
- Underwater repairs, piers and abutments
- High density concrete for shielding
- Concrete and masonry structural repairs
- Underwater concrete

ONE-SOURCE MARINE SERVICES

- Inspections above and below water
- Engineering reports of inspections
- Staff of experienced divers to perform corrective repairs
- Submit budget or firm quotes
- Complete the work based on findings or at the direction of Owner's engineering department or consultant

* Covered by U. S. and Canadian Patents

P. O. BOX 155 • BRECKSVILLE, OHIO 44141 • TELEPHONE 216/659-3141
ATLANTA • BALTIMORE • CHICAGO • DETROIT • FT. LAUDERDALE • HOUSTON • JACKSONVILLE
MINNEAPOLIS • OMAHA • SEATTLE • TORONTO • TULSA
AFFILIATES: LEE TURZILLO CONTRACTING CO. • AUGERCAST PILE & FOUNDATION COMPANY
TURZILLO CONTRACTING LTD.

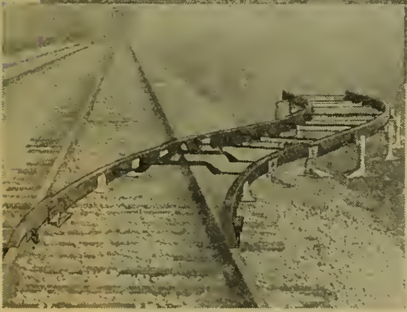
no matter how
you look at it
there is just
one toilet
that stands alone.
one toilet that
has gained
general acceptance
world wide.
one toilet familiar
to all who have ever
flown in an airplane,
traveled in a bus,
sailed in a boat,
or lived in a
recreational vehicle.
the one chemical
retention toilet
now available,
designed especially
to recognize
the rugged requirements,
for all your
sanitation needs:
locomotive
caboose
work equipment . . .
the Vapor NEWMATIC* toilet,
the toilet used
by more than 40 railroads**
become *more* familiar,
write
Transportation Systems Div.
Vapor Corporation
6420 West Howard Street
Chicago, Illinois 60648
In Canada—
Vapor Canada Limited

VAPOR CORPORATION
TRANSPORTATION SYSTEMS DIVISION

*TM Monogram Industries, Inc.
**names furnished on request

How do you handle your heavy machines?

Model M-1400 Portable Ramp for fast, safe unloading of equipment.



Model M-1100 Side Track assembled for set off of M/W equipment.

Model M-1100 Side Track with points and frog removed for train passage.

Safetran has the answer with their PORTABLE RAMPS and SIDE TRACKS

1. **Safetran M-1400 Portable Ramps** can be easily set up in 30 minutes by two men. Ramps are constructed of interlocking, reinforced rectangular steel in easy to handle lengths with telescoping vertical supports. Designed to save time and money by getting machines (up to 60,000 lbs.) on the job faster.

2. **Safetran M-1100 Portable Side Tracks** are to set off machinery close to where the work is to be done. Will handle up to 60,000 lbs. and the fast, simple removal of points and frog allows uninterrupted main line traffic.

For complete details, see Section 16-J in your Safetran M/W Catalog or write:

Safetran Systems Corporation
7721 National Turnpike • Louisville, KY 40214 • (502) 361-1691

EXPERIENCED SPECIALISTS
IN THE REPAIRS OF....
RAILROAD STRUCTURES

Turzillo CORPORATION TM

FOUNDATIONS, UNDERPINNING AND INVESTIGATIONS

AUGERCAST®* Piles — placed without vibration
- For new foundations and underpinning
- Retaining wall piles. Low headroom piles
- Tie-back anchoring system for excavations
- Tension piles and anchors

PRESSURE GROUTING
- BAGPIPE®* Groutainer™ inflatable forming system
- Soil stabilization for arresting settlement of structures
- FIRM-UP® chemical grouting for consolidating soils
- Consolidating masonry bridge abutments and piers

CONCRETE AND MASONRY STRUCTURAL REPAIRS
- Bridges, dams, power plants and dry docks
- Scour repairs
- Tunnel lining repairs
- Repairs to precast, concrete, wood and steel piles

PREPLACED AGGREGATE CONCRETE (PAC)
- Cofferdam seals
- Underwater repairs, piers and abutments
- High density concrete for shielding
- Concrete and masonry structural repairs
- Underwater concrete

ONE-SOURCE MARINE SERVICES
- Inspections above and below water
- Engineering reports of inspections
- Staff of experienced divers to perform corrective repairs
- Submit budget or firm quotes
- Complete the work based on findings or at the direction of Owner's engineering department or consultant

* Covered by U. S. and Canadian Patents

P. O. BOX 155 • BRECKSVILLE, OHIO 44141 • TELEPHONE 216/659-3141
ATLANTA • BALTIMORE • CHICAGO • DETROIT • FT. LAUDERDALE • HOUSTON • JACKSONVILLE
MINNEAPOLIS • OMAHA • SEATTLE • TORONTO • TULSA
AFFILIATES-LEE TURZILLO CONTRACTING CO. • AUGERCAST PILE & FOUNDATION COMPANY
TURZILLO CONTRACTING LTD.

no matter how
you look at it
there is just
one toilet
that stands alone.
one toilet that
has gained
general acceptance
world wide.
one toilet familiar
to all who have ever
flown in an airplane,
traveled in a bus,
sailed in a boat,
or lived in a
recreational vehicle.
the one chemical
retention toilet
now available,
designed especially

to recognize
the rugged requirements,
for all your
sanitation needs:

locomotive
caboose
work equipment . . .

the Vapor NEWMATIC* toilet,
the toilet used
by more than 40 railroads**
become *more* familiar,
write
Transportation Systems Div.
Vapor Corporation
6420 West Howard Street
Chicago, Illinois 60648
In Canada—
Vapor Canada Limited

VAPOR VAPOR CORPORATION
TRANSPORTATION SYSTEMS DIVISION

*TM Monogram Industries, Inc.
**names furnished on request

How do you handle your heavy machines?

Model M-1400 Portable Ramp for fast, safe unloading of equipment.

Model M-1100 Side Track assembled for set off of M/W equipment.

Model M-1100 Side Track with points and frog removed for train passage.

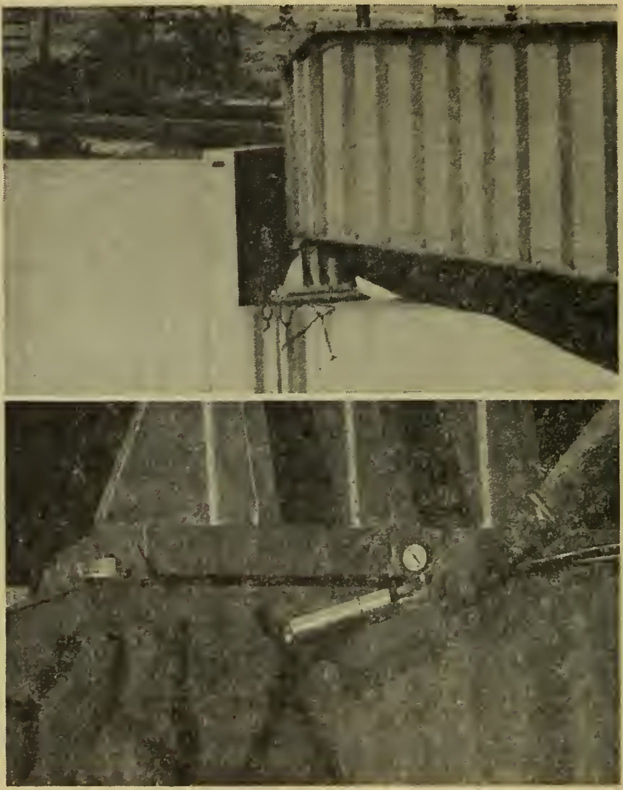
Safetran has the answer with their PORTABLE RAMPS and SIDE TRACKS

1. **Safetran M-1400 Portable Ramps** can be easily set up in 30 minutes by two men. Ramps are constructed of interlocking, reinforced rectangular steel in easy to handle lengths with telescoping vertical supports. Designed to save time and money by getting machines (up to 60,000 lbs.) on the job faster.

2. **Safetran M-1100 Portable Side Tracks** are to set off machinery close to where the work is to be done. Will handle up to 60,000 lbs. and the fast, simple removal of points and frog allows uninterrupted main line traffic.

For complete details, see Section 16-J in your Safetran M/W Catalog or write:

Safetran Systems Corporation
7721 National Turnpike • Louisville, KY 40214 • (502) 361-1691



CONCRETE PROBLEMS?

OSMOSE EPOXY INJECTION MAY BE THE ANSWER

Osmose, the Company synonymous with timber bridges, has now diversified into concrete bridge maintenance, specializing in "welding" structural cracks.

This proven method consists of • ANALYSIS • CLEANING • SEALING • CONTROLLED PRESSURE INJECTION • DETAILED INSPECTION REPORTS

Restores structural integrity under traffic.

OSMOSE **RAILROAD DIVISION**
4915 Monona Drive
Madison, Wis. 53716
608/222-6800

TIE HANDLER from RTW...

with 24-foot-reach articulating boom!

Lifting capacity–1500 lbs. at 12′6″ to 750 lbs. fully extended.

- New rotating deck design ...no adjustments needed
- Thermostatic controlled oil temperature in hydraulic circuit
- Low maintenance
- Hydrodynamic plus mechanical brakes... on all four wheels

Many other features for high production, low maintenance. Choice of two other tubular-type booms (all interchangeable): Fixed 24-ft., and manually adjustable 18-24-ft. From RTW, the people with the longest experience in tie handling. Get full details today. Call (215) 739-4281.

RTW

OTHER RTW MAINTENANCE EQUIPMENT • Switch Grinders • Cross Grinders • Surface Grinders • Rail Drills • Tie Handlers
RAILWAY TRACK-WORK CO. 2560 East Tioga St., Philadelphia, Pa. 19134
Agents: Chicago – ESCO Equipment Service Co. • Houston – Service Equipment & Supply Company
Los Angeles – Simkins Company • Louisville – T. F. Going • St. Louis – R. E. Bell Co.
S. Plainfield, N. J. – Eastern Railroad Equipment Corp. • Canada Montreal – Woodings-Canada Ltd.

MEMBER
RPI
RAILWAY PROGRESS INSTITUTE

TELEWELD
INC.

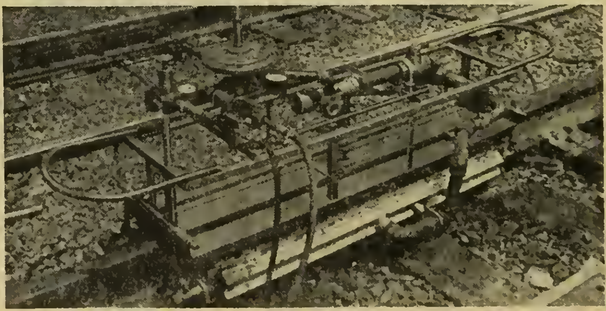
Rail Maintenance Service

Rail End Welding
Rail End Hardening
CWR Joint Normalizing
Frog and Switch Welding

MEMBER
RPI
RAILWAY PROGRESS INSTITUTE

Rail Maintenance Equipment

Custom Manufacturing and Fabrication
Joint Bar Shims
Rail Anchor Shims
Rail End and Frog and Switch
  Welding and Grinding Machines
CWR Heating and Cooling Equipment
Rail Flaw Testing Equipment
Telebrineller Portable Hardness Tester



Infra-Red Heater for Curing Adhesive Bonded Rail Joints

TELEWELD INC., 416 NORTH PARK ST., STREATOR, ILL. 61364
Write for details of the TELEWELD process for restoring rail ends.

REPORT OF EXECUTIVE DIRECTOR

Report of the Executive Director

March 26, 1975

To the Members:

The 1974 Association year was a success from most aspects. One of the bright lights is the level of AREA membership. Last year I reported a decline in membership—a loss of 42 compared with the year before. In 1974, however, the statistics show a gain of 78 members, a remarkable showing in view of the difficult times affecting the general economy. Financially, the AREA had an adequate year in 1974; receipts for the year were sufficient to cover the obligations. To maintain receipts at the highest possible level, the Board of Direction and staff of the Association solicit the active cooperation and support of AREA members by interesting others in becoming members, by paying their annual dues early in the year, and by bringing the AREA Bulletin to the attention of supply companies, contractors and consulting engineers as a prime advertising medium.

The operational year for the AREA began on March 20, 1974, at the end of that year's Technical Conference, and ended on March 26, 1975, at the end of the 1975 Technical Conference.

Major Meetings During 1974 Association Year

The Tenth Regional Meeting of the Association was held at the Hotel Muehlebach, Kansas City, Mo., on November 6, 1974. It was attended by 195 AREA members and guests. The meeting was planned and directed by C. E. Weller, assistant vice president—engineering, Chicago, Rock Island & Pacific Railroad, and chairman of the Board Committee on Regional Meetings; and was presided over by AREA President R. F. Bush, chief engineer, Erie Lackawanna Railway.

Prior to the Regional Meeting at Kansas City, the Board of Direction met with the chairmen, vice chairmen and secretaries of the AREA technical committees to discuss and analyze some of the problems of the committees.

The 74th Technical Conference of the AREA and the 1975 Annual Meeting of the Engineering Division, Association of American Railroads, was held at the Palmer House, Chicago, on March 24–26, 1975. Total registration was 885, comprised of 419 railroad men and 466 non-railroad men. The program of the Conference consisted entirely of features—some general, others sponsored by our technical committees. No committee reports were given since all of them were published in the various issues of the Bulletin prior to the Conference. The Engineering Division session was held on Monday afternoon, March 24, and consisted of reports on the activities of the Division during 1974 and a number of timely and informative addresses and illustrated presentations.

The 1975 meetings were presided over by R. F. Bush, chief engineer, Erie Lackawanna Railway, president of the AREA and chairman of the AAR Engineering Division. The address at the Annual Luncheon was given by G. W. Maxwell, president and chief executive officer, Erie Lackawanna Railway, and a member of AREA.

COMMITTEES OF 1974 BOARD OF DIRECTION

Executive

R. F. Bush, *Chairman*
J. T. Ward
W. J. Jones
R. M. Brown
D. V. Sartore

Membership

B. G. Anderson, *Chairman*
R. W. Pember
B. E. Pearson
P. L. Montgomery
Mike Rougas

Finance

R. F. Bush, *Chairman*
W. J. Jones
B. G. Anderson
E. Q. Johnson
J. W. DeValle

Research

A. L. Sams, *Chairman*
R. M. Brown
D. V. Sartore
B. J. Gordon
C. E. Weller
E. Q. Johnson

Technical Activity

J. T. Ward, *Chairman*
B. G. Anderson
R. W. Pember
W. E. Fuhr
Mike Rougas

Publications

W. J. Jones, *Chairman*
John Fox
C. E. Weller
P. L. Montgomery
J. W. DeValle

Regional Meetings

C. E. Weller, *Chairman*
John Fox
E. Q. Johnson
E. C. Honath
Mike Rougas

Conference Program

John Fox, *Chairman*
J. T. Ward
B. E. Pearson
P. L. Montgomery
J. W. DeValle

Advertising (Special)

R. M. Brown, *Chairman*
R. W. Pember
W. E. Fuhr
B. E. Pearson
E. C. Honath

MEMBERSHIP

As mentioned above, the membership statistics show a gain of 78 during 1974 compared to a loss of 42 during 1973. While gratifying, this gain should not cause a relaxation of efforts on the part of AREA members to interest their friends and associates both inside and outside the railroad industry, and allied to it, in AREA membership. Approximately 250 new members are needed each year simply to overcome normal attrition. A wide range of people are qualified for AREA membership, and would benefit by it as would the Association. These qualifications are given in Article II, Sections A, B, E and F, of the AREA Constitution (see pages 711–713 in this Bulletin). Your help is earnestly solicited in this vital area of Association efforts. Maintaining a high level of membership will help us to retain the annual dues at their present low level.

Another noteworthy aspect of the membership statistics is the further gain in Junior Members experienced in 1974, continuing a trend begun in 1969. Possibly this denotes an increased interest in a railroad career on the part of college graduates since that time.

MEMBERSHIP

	Membership Years			
	1973		*1974*	
Membership as of January 1		3352		3391
New Members during year	108		210	
Reinstatements during year	15		12	
Gain or Loss in Junior Members	+ 13		+ 24	
		136		246
Deceased during year	41		30	
Resigned during year	61		48	
Dropped during year	76		90	
		178		168
Net Gain or Loss	— 42		+ 78	
Membership December 31		3310		3469
		(Corrected to 3391)		

MEMBERSHIP CLASSIFICATION BY YEARS

The year 1967 begins on February 1 and ends on January 31 of the following year. For 1968, the year begins on February 1 and ends on December 31. Each succeeding year begins on January 1 and ends on December 31.

	1967	*1968*	*1969*	*1970*	*1971*	*1972*	*1973*	*1974*
Life	434	433	437	443	451	460	481	620
Member	2665	2659	2577	2579	2502	2549	2492	2502
Associate	265	258	264	257	244	247	232	236
Junior	57	56	55	62	67	96	105	111
Totals	3421	3406	3333	3341	3264	3352	3310 (Corrected to 3391)	3469

Deaths During 1974 Association Year

From May 1, 1974, to May 1, 1975, notice was received at Association Headquarters of the deaths of 32 members, 7 fewer than the previous year and 10 fewer than two years ago.

One of the deceased was a past director (1963–1966) of the Association—**F. N. Beighley** (M '42, L '70), retired roadway engineer, St. Louis–San Francisco Railway. He was also a long-time member of Committee 1—Roadway and Ballast, serving as chairman, 1960–1964.

A number of other deceased members are worthy of note, either for the prominent positions they had attained or for the many years they had devoted to committee service. They are: **F. T. Berry** (M '67), executive officer, operations and maintenance, New York City Transit Authority, member of Committee 32—Systems Engineering, since 1967; **M. B. Davis** (M '24, L '59), retired division engineer, Illinois Central Railroad, member of Committee 1—Roadway and Ballast, 1949–1962; **Randon Ferguson** (M '42, L '67), retired electrical engineer, Association of American Railroads; **H. C. Forman** (M '39, L '64), retired assistant to president, Louisville & Nashville Railroad, member of Committee 14—Yards and Terminals, 1945–1961;

A. J. Greenough (M '40, L '69), retired president, Pennsylvania Railroad; **J. M. Hood** (M '19, L '54), retired president, American Short Line Railroad Association; **H. L. Lansing** (A '40, L '71), retired manager—engineering and manufacturing, Portec, Inc.; **G. F. Nigh** (M '44, L '73), retired division engineer, Norfolk & Western Railway, member of Committee 1—Roadway and Ballast, since 1958, vice chairman, 1970–1973; **J. R. Nutter** (M '48), regional engineer Canadian Pacific Rail, member of Committee 8—Concrete Structures and Foundations, 1953–1958, member of Committee 16—Economics of Plant, Equipment and Operations, 1958–1960, member of Committee 32—Systems Engineering, 1969–1974; **J. P. Ray** (M '41, L '72), retired railroad consultant, member of Committee 25—Waterways and Harbors, 1942–1946, member of Committee 16—Economics of Plant, Equipment and Operations, 1949–1962; **N. B. Roberts** (M '49), regional engineer, Canadian Pacific Rail, member of Committee 3—Ties, 1959–1960, member of Committee 13—Environmental Engineering, 1955–1960, member of Committee 1—Roadway and Ballast, 1962–1971; **H. A. Shinkle** (M '28, L '58), member of Committee 16—Economics of Plant, Equipment and Operations, 1939–1949, member of Committee 11—Engineering Records and Property Accounting, 1946–1961; **C. E. Sloan** (M '25, L '55), retired engineer of bridges and buildings, Baltimore & Ohio Railroad, member of Committee 15—Steel Structures, 1929–1959; **T. H. Strate** (M '20, L '48), retired division engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, member of former Committee 17—Wood Preservation, 1927–1949; **J. S. Wearn** (M '28, L '63), retired assistant chief engineer maintenance of way and structures, Southern Railway, member of Committee 4—Rail, 1950–1964; **O. G. Wilbur** (M '21, L '56), member of Committee 6—Buildings, since 1923, having been elected Member Emeritus in 1960, serving as vice chairman, 1934–1936, and chairman, 1937–1939; **C. R. Wright** (M '20, L '55), retired assistant chief engineer, New York, Chicago & St. Louis Railroad, member of Committee 22—Economics of Railway Construction and Maintenance, 1933–1959, being elected Member Emeritus of that committee in 1961; **J. E. Yewell** (M '20, L '59), member of Committee 15—Steel Structures, 1944–1949, member of Committee 4—Rail, 1949–1959.

ACTIVITIES OF TECHNICAL COMMITTEES

Assignments

During 1974 the 20 standing technical committees of the Association, including the new Special Committee on Scales, which was established by the Board of Direction at its meeting on November 13, 1973, and excluding Committee 31—Continuous Welded Rail, which was merged with Committee 4—Rail, at the conclusion of the last Annual Technical Conference on March 20, 1974, worked on 163 assignments, 25 of which were new (including those of the Scales Committee). The Board Action in establishing the new Special Committee on Scales was in response to a recommendation that the Scales Subcommittee of Committee 14—Yards and Terminals, in view of its highly specialized nature, be removed from that committee, given a separate identity, and have assigned to it scale experts from a greater number of railroads and scale manufacturers to enhance its stature and authority in the eyes of federal and state weights and measures officials.

In addition to the work of the standing committees, the Special Committee on Concrete Ties further revised the preliminary Specification for Concrete Ties (and Fastenings) it had developed and last published in Bulletin 644, September–

October 1973; and recommended that the specification as revised be adopted and published in Chapter 3 of the Manual.

Many of the subcommittees held their own meetings before, during or after the scheduled meetings of the full parent committees. At the full committee meetings, the subcommittee chairmen reported on their assignments and discussed any problems with the work with other members of the full committee. This procedure enables the wide knowledge and experience of all the members of AREA committees, from a large number of railroads, to be applied to the studies of the subcommittees.

AREA committee work is directed toward the preparation of reports for information, toward revising material appearing in the AREA Manual for Railway Engineering and the Portfolio of Trackwork Plans, and toward carrying out special projects related to their assignments.

The 1974 statistics show that our 20 standing committees produced one or more information reports on 34 of their 163 assignments (not including Assignment A). In addition, the standing committees submitted 17 reports containing Manual recommendations, and the Special Committee on Concrete Ties one such report, all of which were published in Part 1 of the November–December Bulletin, separate from the committee reports. Furthermore, most committees presented brief status statements with respect to assignments on which they made no formal report.

During 1975 the technical committees as a whole will work on 165 assignments, 10 of them new.

Classification of Material

The work of AREA committees during 1974 was so diversified that, as in other years, it is impossible to do other than refer to it in general terms in a report such as this. However, the following is a general categorical classification of the results of this work as published in the technical Bulletins of the Association.

Recommendations pertaining to the development, revision or deletion of 31 different specifications and recommended practices for inclusion in the AREA Manual; 26 reports on current developments in engineering practice and design; 3 reports on current developments in systems engineering, data processing and the use of computers to solve problems in railway construction, operation and maintenance; 2 reports dealing with pollution control; 4 reports dealing with the training and recruiting of employees; 2 economic and analytical studies; 3 reports on relations with public authorities; 2 reports dealing with statistics; and 1 bibliography.

Committee work affecting the AREA Manual included the presentation of 2 specifications for adoption; the rewriting or revision of 13 specifications; the presentation of 8 recommended practices for adoption; the revision or rewriting of 6 recommended practices; and the deletion of 5 recommended practices.

Discussion Section

During the 1974 Association year, subcommittee reports, papers and addresses published in the technical issues of the Bulletin were again advertised as open for discussion.

Personnel of Committees

At the beginning of the 1974 Association year 1090 members were assigned to 1186 places on the Association's 20 technical committees. This compares with

1023 members assigned to 1143 places at the beginning of the previous year. In addition, 11 members were assigned to the Special Committee on Concrete Ties.

AREA committees again were limited to a maximum membership of 70 and to the number from each railroad depending on the total number of AREA members on the railroad.

In the 1974 Handbook of Committee Activity the names of committee chairmen, vice chairmen, secretaries and subcommittee chairmen were again shown in boldface type at the head of each committee roster.

The number of members so far assigned to committees for 1975 (as of March 1) is less than a year ago; specifically 1072 members assigned to 1166 places.

Committee Meetings

To progress work on their assignments the 20 standing AREA technical committees held a total of 46 meetings during the 1974 Association year, the same number as during the previous year. In addition, the Special Committee on Concrete Ties held 1 meeting in 1974. As is usually the case, the majority of these meetings were held in Chicago or at points central to the largest number of committee members. The exceptions were scheduled to permit inspections of facilities, operations or projects which could be seen only by going to those points.

Of the 46 meetings held during the 1974 Association year, 23 were held in Chicago (including the 7 held in March during the 1974 AREA Technical Conference and the 5 held during the 1974 Roadmasters' and Bridge & Building Associations Convention); 2 each were held in Tampa, Fla., Columbia, S.C., San Francisco, Calif., and New Orleans, La., and 15 were held in as many other cities.

The number of meetings held during the year by each committee was dictated by the scope of its work and other considerations. Accordingly, 1 committee held 4 meetings, 7 committees each held 3 meetings, 9 committees each held 2 meetings, and 3 committees each held 1 meeting.

ASSOCIATION PUBLICATIONS

In 1974 the AREA Bulletin was again published on the scheduled five-time basis. The Bulletins in Proceedings Volume 76, 1975 are Nos. 649, September–October 1974, 650, November–December 1974; 651 January–February 1975; and 653, June–July 1975. Bulletin 652 is the blue-covered April–May Directory Issue, which is not a part of the Annual Proceedings of the Association.

The 1974 Handbook of Committee Activity was published in April and distributed to all committee members at that time.

The 1974 Supplement to the AREA Manual for Railway Engineering has not yet been published because of a number of unrectified problems within the Manual Recommendations as published in Part 1 of the November–December 1974 Bulletin. There will be no Supplement to the AREA Portfolio of Trackwork Plans for 1974.

A letter dated January 27, 1975, was sent to owners of the Manual and Portfolio in regard to the availability of the 1973 Manual and Portfolio Supplements. Attached to this letter was an order form for purchasing one or more copies of these 1973 Supplements or any back issues that might be needed. The member price of the 1973 Manual Supplement was established as $6.00 each, and of the Portfolio Supplement, $3.00 each. The non-member prices of these publications were established at $9.50 and $5.50, respectively. Publication of the 1973 Supplement was held up much beyond the normal publication date to permit inclusion therein of the completely revised and reorganized data on track scales in Manual Chapter 14—Yards and Terminals.

Another letter, this one dated January 22, 1975, was sent to AREA members in regard to the availability of Bulletin Binders—Volume 74 (1973) and 75 (1974). Attached to this letter was a simple order form for the use of members desiring to purchase one or more copies of these binders. The member price of the Volume 74 binder was established at $3.00 each; the Volume 75 binder, $3.50 each. Each of these hard-cover book-type binders is designed to house all the Bulletins in a publication year, which starts with the September–October issue and ends with the June–July issue, with the exception of the blue-covered April–May Directory issue which is not punched for binding.

The June–July 1974 Bulletin contained all material presented at the March 1974 Technical Conference having technical and historic interest—the president's address, reports of the executive director and treasurer, special features, panel discussions, and committee reports not previously published in the committee report Bulletins.

LOOKING AHEAD

The 1976 Technical Conference of the AREA will be held at the Palmer House, Chicago, on March 22–24.

The next Regional Meeting will be held at Vancouver, B. C., Canada, on October 30, 1975. Arrangements and Planning for the meeting are under the direction of AREA Vice President John Fox, assistant chief engineer, Canadian Pacific Rail. In 1976 the Regional Meeting will be held at Pittsburgh, Pa.

As reported, our membership level remains high, considering the reduction in the number of engineering employees on the railroads, the economic recession and other factors which prevent participation in Association activities, and our financial situation remains sound—the Association is still going strong. Keeping it that way will require that the Association accomplish its professional responsibilities in behalf of the engineering profession and the railroad industry expeditiously and efficiently, and this it can do with the active support of its officers, directors and members, and all railroad engineering and maintenance officers.

Respectfully submitted,

Earl W. Hodgkins,
Executive Director and Secretary

Deceased Members

W. G. BAILEY (M '63)
District Engineer, Atchison, Topeka & Santa Fe Railway, Amarillo, Tex.

C. M. BARDWELL (A '24, L '59)
Houston, Tex.

F. N. BEIGHLEY (M '42, L '70)
Retired Roadway Engineer, St. Louis–San Francisco Railway, Springfield, Mo.

F. T. BERRY (M '67)
Executive Officer, New York City Transit Authority, Brooklyn, N. Y.

R. B. CARRINGTON, JR. (M '49)
President, Cougar Construction Company, Richmond, Va.

M. B. DAVIS (M '24, L '59)
Retired Division Engineer, Illinois Central Railroad, Waterloo, Ia.

J. L. ENGLER (M '64)
Construction Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kans.

RANDON FERGUSON (M '42, L '67)
Retired Electrical Engineer, Association of American Railroads, Park Forest, Ill.

H. C. FORMAN (M '39, L '64)
Retired Assistant to President, Louisville & Nashville Railroad, Louisville, Ky.

A. J. GREENOUGH (M '40, L '69)
Retired Special Consultant, Penn Central Transportation Company, North Salem, N. Y.

R. A. GRIMM (M '68)
Assistant Division Engineer, Union Pacific Railroad, Pocatello, Ida.

J. M. HOOD (M '19, L '54)
Retired President, American Short Line Railroad Association, Washington, D. C.

J. M. HOPKINS (M '55)
Senior Project Engineer, Elgin, Joliet & Eastern Railway, Joliet, Ill.

E. J. HYNES (M '57)
Assistant Engineer, Detroit, Toledo & Ironton Railroad, Dearborn, Mich.

T. H. JENKINS (M '47, L '72)
Retired Engineer of Bridges and Structures, Canadian National Railways,
Town of Mount Royal, Que.

B. O. JOHNSON (M '53)
Retired Office Engineer, Milwaukee Road, Tucson, Ariz.

T. W. LANDERS (M '55)
Engineer, Quebec North Shore & Labrador Railway, Sept Isles, Que.

H. L. LANSING (M '40, L '71)
Retired Manager—Engineering and Manufacturing, Portec, Inc., Islesboro, Me.

G. F. NIGH (M '44, L '73)
Retired Division Engineer—Construction, Norfolk & Western Railway, St. Petersburg, Fla.

J. R. NUTTER (M '48)
Assistant Regional Engineer, Canadian Pacific Limited, Winnipeg, Man.

O. R. PRICE (M '11, L '42)
Retired Assistant Engineer, Western Maryland Railway, Miami, Fla.

J. P. RAY (M '41, L '72)
Retired Railroad Consultant, Vogt, Ivers and Associates, Cincinnati, Ohio

N. B. ROBERTS (M '49)
Regional Engineer, Canadian Pacific Limited, Toronto, Ont.

H. A. SHINKLE (M '28, L '58)
Retired Valuation Engineer, Atchison, Topeka & Santa Fe Railway, Shawnee Mission, Kans.

C. E. SLOAN (M '25, L '55)
Retired Engineer of Bridges and Buildings, Baltimore & Ohio Railroad, Florence, Ky.

T. H. Strate (M '20, L '48)
Retired Division Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, San Ysidro, Calif.

T. H. Taylor (M '51, A '69)
Sales Engineer, Western Cullen Division, Chicago

J. S. Wearn (M '28, L '63)
Retired Assistant Chief Engineer, Maintenance of Way and Structures, Southern Railway System, Chapel Hill, N. C.

O. G. Wilbur (M '21, L '56)
Retired Assistant Engineer of Bridges and Buildings, Baltimore & Ohio Railroad, Ft. Lauderdale, Fla.

C. R. Wright (M '20, L '55)
Retired Assistant Chief Engineer, New York, Chicago & St. Louis Railroad, Cleveland, Ohio

J. E. Yewell (M '20, L '59)
Retired Chief Engineer, Bessemer & Lake Erie Railroad, Greenville, Pa.

J. A. Young (M '26, L '60)
Retired District Engineer, Northern Pacific Railway, Seattle, Wash.

REPORT OF TREASURER

Report of the Treasurer

December 31, 1974

To the Members:

The AREA budget for the year 1974 was very nearly balanced between receipts and expenditures. On last December 31, the financial statement showed $400 more receipts than expenditures, but at a level about $8000 less than estimated and about $4000 more than actual receipts and expenditures for 1973. This situation will look good should the U. S. Internal Revenue Service decide to audit the AREA financial activity during 1974. The IRS has done this 4 times in the past 12 years, which is a way of life for not-for-profit organizations.

So far as receipts are concerned, membership accounts were down only $1500 from estimate; publication sales down $5500; and advertising down $3000. Conference receipts were up $2100 but just barely covered actual cost because of the increases in hotel services and projection equipment. Other receipt items were close to estimate.

A look at 1974 expenditures shows that printing was down $4000 from estmate; shipping expenses down $3000; and conference costs up about $2000. The level of salaries and wages virtually matched the estimates.

The level of the AREA's total financial depositories in 1974 remained about the same as 1973. Surplus funds are invested in United States Treasury bonds and notes, although an adequate amount of money is maintained in a savings account to protect the AREA checking account for the payment of bills and salaries and wages.

Financially speaking, the AREA had an adequate year in 1974 since receipts for the year were sufficient to cover the financial obligations. However, for your information, the approved budget for 1975 anticipates that expenditures will exceed receipts by more than $11,000. This is due entirely to replacing the inventory of binders for the two-volume Manual For Railway Engineering (Fixed Properties) and will be recaptured over two or three years from the sale of Manuals.

The Board of Direction and staff of the Association solicit the active cooperation and support of AREA members by interesting others in becoming members, by paying their annual dues early in the year, and by bringing the AREA bulletin to the attention of railway supply companies, contractors, and consulting engineers as a prime advertising medium.

Following is the General Balance Sheet for December 31, 1974; the Statement of Receipts and Expenditures for Calendar Year 1974; the Comparative Statement of Receipts and Expenditures for the Last 20 years; and the Comparative Statement of Association Equity as of December 31, 1973 and 1974.

A. B. Hillman, Jr., *Treasurer*

GENERAL BALANCE SHEET

DECEMBER 31, 1974

Assets:			
Cash:			
Checking Account	$ 2,425.88		
Special Deposit	81,909.45		
Petty Cash	50.00		
Total Cash		$84,385.33	
Accounts Receivable		974.65	
Inventory of Publications:			
Manual for Railway Engineering	$ 10,100.00		
Portfolio of Trackwork Plans	3,300.00		
Bulletins	300.00		
Proceedings	100.00		
Newsletter	......		
Other Publications	110.00		
Total Inventory of Publications		13,910.00	
Other Assets:			
*Prepaid Postage	$ 1,551.72		
Furniture and Fixtures	1,000.00		
Investments	42,000.00		
Total Other Assets		44,551.72	
Total Assets			$143,821.70
Liabilities and Association Equity:			
Member Dues Paid in Advance	$		
Association Equity	143,821.70		
Total Liabilities and Association Equity			$143,821.70

---

*Prepaid Postage:	
Second Class deposit—Madison	$ 150.00
Postage Meter	1,311.72
Postal Stamps	90.00
Total Prepaid Postage	$ 1,551.72

STATEMENT OF RECEIPTS AND EXPENDITURES
CALENDAR YEAR 1974

RECEIPTS

Current Receipts:		
Membership Accounts:		
Member and Associate Dues	$56,838.50	
Student Affiliate Dues	30.00	
Entrance Fees	1,675.00	
Total Membership Accounts	$58,543.50	
Publications:		
Manual For Railway Engineering	$17,186.92	
Portfolio of Trackwork Plans	5,184.25	
Bulletins	3,600.25	
Proceedings	3,024.50	
Specifications	1,433.35	
Handling and shipping	2,897.89	
Total from Publications	$33,327.16	
Other Sources:		
Advertising in Publications	$ 7,043.12	
Annual Conference Registration Fees	7,612.66	
Interest on Investments	5,875.00	
Miscellaneous	148.46	
Total Other Sources	$20,679.24	
Total Receipts		$112,549.90

EXPENDITURES

Current Expenses:		
Salaries and Wages	$35,001.00	
Soc. Security and Ins. Unempl. Tax	3,073.47	
Retirement Benefits	3,152.28	
Manual For Railway Engineering	14,223.25	
Portfolio of Trackwork Plans	148.00	
Bulletins and Proceedings	30,059.80	
Newsletter	1,363.51	
Shipping Charges	5,175.90	
Stationery and Printing	3,906.03	
Supplies	377.87	
Refunds and Miscellaneous	998.72	
Rent	1,140.00	
Telephone	424.23	
Committee and Traveling Expenses	938.66	
Professors Expenses	4,642.92	
Annual Conference	7,402.96	
Extraordinary	124.90	
Total Expenditures		$112,153.50
Excess of Receipts over Expenditures		$ 396.40

COMPARATIVE STATEMENT OF RECEIPTS AND EXPENDITURES FOR THE LAST 20 YEARS

	Receipts	*Expenditures*	*Increase or (Decrease)*
1955	$ 80,177.21	$ 73,923.18	$ 6,254.03
1956	79,351.11	70,336.17	9,014.94
1957	85,429.31	89,830.57	(4,401.26)
1958	81,454.56	77,348.92	4,105.64
1959	80,407.16	80,297.48	109.68
1960	81,138.79	83,978.29	(2,839.50)
1961	83,461.73	73,410.20	10,051.53
1962	76,097.28	87,344.12	(11,246.84)
1963	73,653.48	66,156.99	7,496.49
1964	74,834.81	78,118.66	(3,283.85)
1965	81,336.73	73,895.90	7,440.83
1966	84,590.91	80,454.00	4,136.91
1967	78,724.17	101,087.51	(22,363.34)
1968	97,639.94	111,054.20	(13,414.26)
1969	109,893.16	112,741.62	(2,848.46)
1970	113,245.85	108,305.33	4,940.52
1971	113,756.51	116,003.93	(2,247.42)
1972	128,208.01	125,534.70	2,673.31
1973	110,193.20	108,148.33	2,044.87
1974	112,549.90	112,153.50	396.40

COMPARATIVE STATEMENT OF ASSOCIATION EQUITY AS OF DECEMBER 31, 1973 AND 1974

	1974	*1973*	*Increase or (Decrease)*
Assets:			
*Cash	$ 84,385.33	$ 13,383.10	$71,002.23
Accounts Receivable	974.65	(438.26)	1,412.91
Inventory of Publications	13,910.00	12,405.14	1,504.86
*Other Assets	44,551.72	113,625.51	(69,073.79)
Total Assets	$143,821.70	$138,975.49	$ 4,846.21
Liabilities and Association Equity:			
Member Dues Paid in Advance	$	$ 651.17	$ (651.17)
Association Equity	143,821.70	138,324.32	5,497.38
Total Liabilities and Association Equity	$143,821.70	$138,975.49	$ 4,846.21

---

* Includes Transfer of $70,000.00 from Investments to Special Deposit.

CONSTITUTION

American Railway Engineering Association

CONSTITUTION

Revised to February 8, 1974

Article I

Name, Object and Location

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Study and Research Committees.

(b) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

Article II

Membership

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. General

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than 25 years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereof, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

B. MEMBER

A Member shall be:

(a) A railway engineer or officer who has had not less than five years' experience in the location, construction, operation or maintenance of railways and who is employed by a common-carrier railway corporation, by an approved association of railroads or railway engineers or officers, or by a non-common-carrier railway if primary duties consist entirely or primarily of the location, construction, operation or maintenance of a railway plant and facilities.

(b) A dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency who, in the discharge of regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer or contractor, or an engineer in their employ, engaged in the engineering, construction and maintenance of railroad-related facilities or an engineer employed by a technical service or research and development organization who has had the equivalent of five years' engineering experience.

(f) An officer or engineer of an engineering or scientific society or association whose aims and objectives are compatible with the aims and objectives of this association.

C. LIFE MEMBER

A Life Member shall be a Past President of the Association who has been retired under a recognized retirement plan, or a Member or an Associate who has paid dues for 35 years or who has been retired under a recognized retirement plan and has paid dues for not less than 25 years.

D. HONORARY MEMBER

(a) An Honorary Member shall be a person of acknowledged eminence in railways engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. ASSOCIATE

An Associate shall be:

(a) A member of a railway supply company or association who meets the qualifications of Section 2, Paragraph A (a) and (b).

(b) A person qualified by training and experience to cooperate with Members in the object of this Association, but who is not qualified to become a Member.

F. JUNIOR MEMBER

(a) A Junior Member shall be not less than 21 years of age, shall have had not less than three years' experience in the location, construction, operation or maintenance of railways, and shall be an employee of a railway corporation, or one of the organizations or institutions listed under Section B of this Article, or a railway supply company if qualified under Section 2, Paragraph A (b) of this Article.

(b) Membership in this classification in the Association shall terminate at the end of the calendar year in which individual becomes 30 years of age.

(c) A Junior Member may make application for membership in another grade at any time when eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership, any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members, and Life Members who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

ADMISSION, RESIGNATION, EXPULSION AND REINSTATEMENT

1. Charter Membership

The Charter Membership of this Association consisted of all persons elected to membership before March 15, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these Members shall be requested to certify to a personal knowledge of the applicant with an opinion of the applicant's qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom the applicant is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested to certify to a personal knowledge of the applicant, with an opinion of the applicant's qualifications for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with the required information, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible, and the admission of the applicant shall be canvassed by ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provision of Section 2, Paragraphs (a) and (c) of the Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

An applicant for any class of membership in this Association shall declare willingness to abide by the Constitution of the Association in the application for membership.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, the person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be reauired for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

ARTICLE IV

DUES

1. Entrance Fee

(a) An entrance fee of $10 shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) An entrance fee of $5 shall be payable to the Association with each application for Junior Member, which sum shall be returned to an applicant not elected. When a Junior Member transfers to the Member or Associate Member class the previously paid $5 entrance fee shall be credited towards the entrance fee for the class to which transferring. However, the Junior Member entrance fee shall not be returnable should the individual resign from the Association or allow membership to lapse. Neither shall it be applicable to the dues for any year.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $20.

(b) The annual dues for each Junior Member shall be $7.50.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Executive Officer-Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he or she is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he or she will no longer receive the publications of the Association. If the dues are not paid by December 31, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

OFFICERS

1. Officers

(a) The officers of the Association shall be a President, two Vice Presidents, two Past Presidents, twelve Directors, an Executive Officer-Secretary, and a Treasurer.

(b) The President, the Vice Presidents, the Directors and the two Past Presidents on the Board of Direction shall be Members and shall act as the trustees and have the custody of all property belonging to the Association.

(c) The Executive Officer-Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice Presidents two years and of the Directors three years. The term of each shall begin at the close of the annual technical conference at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position at the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected prior to or at each annual technical conference a President, one Vice President and four Directors.

(b) The candidates for President and for Vice President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

6. Vacation of Office

(a) In the event of the death of an elected officer, or resignation from office, or if the officer should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past President who is a member of the committee shall be the chairman of the committee. In the absence of the senior Past President from a meeting of the committee the Past President next in seniority present shall act as chairman.

(d) If one or more Past Presidents are unable to act as members of the committee through disability, the President shall have the authority to appoint an equivalent number of eligible next senior Past Presidents to the committee as ordinary members.

(e) If one or more elected members of the committee are unable to act, through death or disability, the President shall have the authority to appoint as replacements an equivalent number of the senior unsuccessful candidates for election to the committee.

2. Method of Nominating

(a) At least three months prior to the annual technical conference, the Chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The nominations for Director shall maintain the territorial balance prescribed in Article VII, Section 1, Paragraph (b), to the maximum extent practicable. In this connection, the nominations for Director shall be predicated, insofar as practicable, on the following three-year repeating pattern of Director positions to ensure adequate territorial distribution:

First Year	Second Year	Third Year
East—2	East—1	East—1
South—1	West—2	South—1
West—1	Canada—1	West—2

Nominations in any one year shall be double the number of positions available for each district that year, with the nominations listed separately by districts.

(c) The elected members of the Nominating Committee each year shall include one from each district represented on the Board of Direction and one at-large member. Nominations in any year shall be double the number of positions available for each district, with the nominations listed separately by districts.

(d) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Executive Officer-Secretary within 15 days after the meeting of the Nominating Committee, and the Executive Officer-Secretary shall report the names of these nominees to the members of the Association not less than 60 days prior to the annual technical conference.

(e) At any time prior to 30 days before the annual meeting of the Nominating Committee, any ten or more Members may send to the Executive Officer-Secretary nominations for any elective office for the ensuing year for consideration by the Nominating Committee, signed by such Members.

(f) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than 60 days prior to each annual technical conference, the Executive Officer-Secretary shall issue a ballot to each voting Member of record who has paid dues to or beyond December 31 of the previous year, listing by districts the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order within each district that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his or her record of membership and activities in the Association.

4. Substitution of Names

Members may remove names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Executive Officer-Secretary at any time previous to the closure of the polls.

(b) A voter may have the privilege of withdrawing his ballot, for the purposes of casting another, or otherwise, at any time up to ten working days prior to the closure of the polls. After that date, no ballot shall be subject to withdrawal or revision.

(c) Ballots received in unendorsed envelopes, or from persons not qualified to vote, shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at 12 o'clock noon at least 30 days, but not more than 45 days, prior to the first day of the annual technical conference. The ballots shall be counted soon thereafter by tellers appointed by the President of the Association.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the annual technical conference shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the annual technical conference the names of the officers elected in accordance with this Article.

Article VII

MANAGEMENT

1. Board of Direction

(a) The Board of Direction shall be the governing body of the Association and shall manage the affairs of the Association in accordance with the Constitution of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution. It shall be composed of seventeen Members of the Association, and shall include the President and two Vice Presidents of the Association, the two living junior Past Presidents, and twelve elected Directors. The nomination and election of the Officers and Directors shall be in accordance with the procedures set forth in Article VI herein.

(b) Furthermore, the membership shall, insofar as possible, include proportional representation from the territorial divisions contained in the "List of Principal Railroads Showing Allocation to Geographical Groups" (published in the current issue of The Official Railway Equipment Register).

Accordingly, the twelve Directors shall be elected in accordance with Article VI, Section 2, to fit, insofar as possible, the following general plan for territorial representation:

Four from the Eastern District; two from the Southern District; five from the Western District, including the Northwestern, Central Western and Southwestern Districts; and one from Canada.

(c) The President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction shall be at-large members of the Board.

(d) Vacancies occurring in Director positions prior to normal expiration of term of office shall be filled by the Board, insofar as possible, from the district represented by the previous incumbent.

(e) The Board of Direction shall meet within thirty days after each annual technical conference, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(f) Seven members of the Board of Direction shall constitute a quorum.

2. Executive Committee

(a) An Executive Committee of the Board of Direction shall be constituted annually and shall consist of the President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction. The Executive Committee shall be subject to confirmation of the Board of Direction each year at the first meeting of the Board following the Convention. The President of the Association shall be the chairman of the Executive Committee.

(b) The Executive Committee shall possess and may exercise during intervals between meetings of the Board, all of the powers of the Board on matters which in the judgment of a majority of the Executive Committee cannot properly be delayed until the next meeting of the Board. Actions of the Executive Committee shall be authorized by a concurring majority of its full membership and shall be reported to the Board of Direction at its next meeting.

(c) The Executive Committee may be dissolved at any time by action of a majority of the full membership of the Board of Direction. Following such dissolution, the Executive Committee may be re-created with personnel different than prescribed in Paragraph (a) herein at any time prior to the annual technical conference by action of a majority of the full membership of the Board. However, if the Executive Committee is not re-created prior to the next annual technical conference it automatically shall come under the provision of Paragraph (a) herein unless the Board of Direction decrees otherwise.

3. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association, the Board of Direction and the Executive Committee of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

4. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

5. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Executive Officer-Secretary and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

6. Executive Officer-Secretary

The Executive Officer-Secretary of the Association shall be appointed by the Board of Direction to manage the affairs of the Association under the direction of the President and the Board of Direction. This officer shall use the title "Executive Director," or such other title as the Board of Direction may direct, except that on legal papers or on other documents, at his or her discretion, the title "Secretary" shall be used. This officer shall serve as secretary of the Board of Direction and of the Executive Committee of the Board of Direction.

The Executive Officer-Secretary shall attend the meetings of the Association, the Board of Direction, and the Executive Committee of the Board of Direction, prepare the business therefor, and record the proceedings thereof. Furthermore, this officer shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the

Treasurer therefor. This officer shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. In addition, shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee of the Board of Direction and approved by the Board of Direction, with notification to the Treasurer of such investments.

The Executive Officer-Secretary shall be responsible for the handling of the correspondence of the Association, shall make an annual report to the Association, shall have direct charge of the property and quarters of the Association, shall direct the work of the secretaries, assistant secretaries and other employees of the Association, and shall perform such other duties as the Board of Direction may prescribe.

7. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

8. Administrative Committees

At the first meeting of the Board of Direction after the annual technical conference, the following Administrative Committees, each consisting of not less than three members, shall be appointed by the President. The personnel of these committees shall be subject to approval by the Board of Direction.

Finance
Membership
Publications
Research
Technical Activity
Conference Program

Other special Administrative Committees may be appointed by the President at any time, and reappointed annually, if necessary, their personnel being subject to approval by the Board of Direction.

Membership on Administrative Committees shall be restricted to members of the Board of Direction, except that one or two members of the Administrative Committee on Research may be past members of the Board of Direction.

9. Study and Research Committees

The Board of Direction may establish continuing or special Study and Research Committees to investigate, consider, and report upon subjects appropriate to the object of the Association, as set forth in Art. I.

10. Duties of Administrative Committees

(a) Finance

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of funds and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Membership

The Membership Committee shall investigate applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(c) Publications

The Publications Committee shall have general supervision over the publications of the Association, including the Manual and the Portfolio. The Publications Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(d) Research

The Research Committee shall encourage and coordinate the research activities of the Association, in the course of accomplishment of which it shall review and pass upon the recommendations of Study and Research Committees for research projects and shall report thereon to the Board of Direction, recommending for approval specific projects initiated by these committees or by the Research Committee and recommending allotments of funds for these projects in the research budget of the Association of American Railroads or from other sources compatible therewith; shall collaborate closely with the research staff of the Association of American Railroads and other organizations; and when called upon by the Vice President—Research or the Vice President—Operations and Maintenance of that association, members of the Research Committee shall engage in the activities of advisory committees or groups of that organization and shall report from time to time to the Board of Direction on those activities.

(e) Technical Activity

The Technical Activity Committee shall monitor and give direction to the activities of Association Study and Research Committees, and review the activity of the personnel assigned thereto. It shall review and pass upon the recommendations of those committees for subjects to be investigated, considered, and reported on by those committees during the ensuing Association year, and shall report thereon to the Board of Direction for its approval. The Technical Activity Committee shall have authority to assign additional subjects or change the scope of any existing subjects at any time during the year, reporting its action thereon to the Board at its next regular meeting.

This Committee also shall review and pass upon applications of members for appointment to Study and Research Committees, and shall appoint the chairman and vice chairman of each such committee and make a report thereon to the Board of Direction for its approval. Should an unexpected vacancy in the chairmanship or vice chairmanship of any such committee occur, the Technical Activity Committee shall have authority to fill such vacancy immediately, reporting its action thereon to the Board at its next regular meeting.

(f) Conference Program

The Conference Program Committee shall develop the program of the annual technical conference with the assistance of the Study and Research Committees, the Board of Direction, the Executive Officer-Secretary, and others.

11. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

12. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

13. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual technical conference of the Association shall be deemed to be the act of the Association.

Article VIII

MEETINGS

1. Annual Technical Conference

(a) The Annual Technical Conference of the Association shall be held in the City of Chicago, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The technical conference in any year shall be held on dates determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Executive Officer-Secretary shall notify all members of the Association of the time and place of the annual technical conference at least 30 days in advance thereof.

(c) The order of business at the annual technical conference of the Association shall be:

Address of the President
Reports of the Executive Officer-Secretary and the Treasurer
Committee and other presentations
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by the presiding officer.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to Members and to those others invited by the presiding officer to speak.

2. Special Meetings

Special meetings of the Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five Members shall constitute a quorum at all meetings of the Association.

Article IX

AMENDMENT

1. Amendment

Amendment of this Constitution may be proposed by written petition signed by not less than ten Members of the Association, and shall be acted upon in the following manner:

The proposed amendment shall be presented to the Executive Officer-Secretary who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes, the matter shall be submitted to the voting members of the Association by letter ballot.

Amendment to the Constitution also may be proposed by majority affirmative vote of the entire Board of Direction, and the proposed amendment then submitted to the voting members of the Association by letter ballot.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association.

Index to Proceedings, Vol. 76, 1975

— A —

AAR Engineering Division (see Engineering Division, AAR)
Accounting, bibliography, 261
AFE projects, answers to questionnaire on status of, 262
—form for reporting status of, Manual recommendations, 224
Ahlf, R. E., address, "Heavy Four-Axle Cars and Their Maintenance of Way Costs," 622
Annual Technical Conference, installation of officers, 645
—program, 451

— B —

Ballast, prepared stone, slag and gravel, specifications for, Manual recommendations, 145
Bechly, D. S., address, "Activity Relative to Flood Plains and Potential Effect on Railroad Installations," 514
Beck, R. F., address, "New Vertical Lift Bridge Over Chicago's Calumet River," 432
Bibliographies, engineering records and property accounting, 261
Boley, H. C., memoir, 260
Bridges, continuous welded rail on, Manual recommendations, 242
Bridges, steel railway, specifications for, Manual recommendations, 240
Bridge timbers, evaluation of cost of various sizes, 317
Bridges, wood, concrete cap for, 321
—design specifications, Manual recommendations, 232
Brohaugh, R. G., address, "A Planning, Scheduling and Reporting System for MW&S Basic Force," 437
Buildings, committee report, 299
—metal, pre-engineered, Manual recommendations, 179
—portable crew housing, 301
—sanitation requirements, 347
—railway office, design criteria for, Manual recommendations, 167
—railway passenger stations, design criteria for, Manual recommendations, 185
Busby, J. S., address, "An Outline of the Past, Present and Future of Engineering Training on Canadian National Railways, with Emphasis on Roadmaster Training," 536
Bush, R. F., president's address, 459
—remarks at Engineering Division, AAR, Annual Meeting session, 651

— C —

Canadian National Railways, outline of past, present and future of engineering training, with emphasis on roadmaster training, 536
Car rollability, design criteria for study of, 268
Cars, freight, with characteristics approaching limits of acceptable design, economics of, 137
Cars, heavy, four-axle, their maintenance of way costs, 622
—issues in use of, 616
Cast steels, fracture mechanics and plane strain fracture toughness of, 665
Chamberlain, H. L., address, "Organization and Field Work," in connection with USRA study, 578
Chessie System, service tests of standard carbon steel rail and various wear-resistant rails, 99
Clearances, committee report, 361
—equipment diagrams, 235, 236, 237
—state legal requirements, 234
—tables for computing mid-ordinates and curve offsets on loads, 234
College graduates, employed by railroads August 1973 to July 1974, 374
College students, engineering, summer employment of, 381
Communications, effect of railroad electrification on, 384
Computers, room design for, 310
—usage of in SP's engineering department, 368
Computers, digital, applications to classification yards, 272
Concrete cap, precast, prestressed, for use in timber trestles, 321
Concrete members, design specifications, Manual recommendations, 205
Concrete repair, by epoxy injection, 435
Concrete Structures and Foundations, committee report, 319
Concrete ties (see Ties, concrete)
Constitution, AREA, 709
Continuous welded rail, on bridges, Manual recommendations, 242
Corrosion, control of in engine cooling systems, Manual recommendations, 230
Cox, B. G., report, "New York City Transit Authority Stores Operations," 364
Crossing design, 410
Crossing frogs, types of in use as related to speed, tonnage, etc., 410
Crossings, highway–railway grade, bituminous, construction specifications, Manual recommendations, 219
—general specifications for, Manual recommendations, 219
—National Rail–Highway Crossing Program, status report from a highway viewpoint, 509
—status report from a railway viewpoint, 504
—prefabricated sectional treated timber, construction specifications, Manual recommendations, 221
—safety, reports relating to, 250
—warnings, train actuated, evaluation of developments, 256
—wood plank, construction specifications, Manual recommendations, 221

— D —

Davis, H. R., introduction to addresses on "Engineering Systems Approach to Study for United States Railway Association," 576
Department of Transportation, High-Speed Ground Test Center at Pueblo, Colo., 328
Depreciation, current developments in connection with regulatory bodies and courts, 264

— E —

Economics of Plant, Equipment and Operations, committee reports, 137, 327
Economics of Railway Construction and Maintenance, committee report, 327
Edgerton, R. C., address, "The Transportation Research Board—Its Organization and Functions" 465
Education (see Engineering Education)

Ekrem, N. E., address, "Restoration of Traffic Following Derailment and Fire on Truss Bridge," 519
Election of officers, nominating committee, 455
—successful candidates, 456
—tellers committee, 455
Electrical Energy Utilization, committee report, 383
Electrification, effect of on signals and communications, 384
Engine cooling systems, corrosion control in, Manual recommendations, 230
Engineering Division, AAR, Annual Meeting Session, 649
—remarks by Chairman R. F. Bush, 651
Engineering Education, committee reports, 125, 373
—continuing, 125
—exchange of professional staffs, 128
Engineering Records and Property Accounting, committee report, 259
Engines, for maintenance of way work equipment, selection of, 355
Environmental Engineering, committee report, 341
Executive director, report of, 693

— F —

Farris, J. B., address, "Roadbed Stabilization —Various Methods," 419
Finnell, J. L., address, "Railroad Scales—Past, Present and Future Applications," 523
Flood plains, potential effect of activity relating to on railroad installations, 514
Foundations, spread footing, design specifications, Manual recommendations, 206
Fracture mechanics, cast steels, 665
Freight cars (see Cars, freight)

— G —

Gangs, maintenance of way and structures, portable housing for, 301
Groves, M. T., report, "Fracture Mechanics and Plane Strain Fracture Toughness of Cast Steels," 665

— H —

Hankins, V. C., memoir, 410
Heavy Cars (see Cars, heavy)
High-Speed Ground Test Center, description of, 328
Highway–railway grade crossings (see Crossings, highway–railway grade)
Highways, committee report, 249
Hillman, A. B., Jr., treasurer, report of, 703
Hodgkins, E. W., executive director, report of, 693
Holt, R. W., address, "Track Geometry Car, Management Uses," 561
Howell, R. P., address, "Rehabilitation Planning and Cost Estimating Phase of the USRA Inventory and Assessment Project," 589
Hygiene, industrial, OSHA (FRA) general environmental controls, Manual recommendations, 226

— I —

Industrial hygiene (see Hygiene, industrial)
Interstate Commerce Commission, accounting classifications, revisions and interpretations, 265

— K —

Kauffman, S. K., report, "New York City Transit Authority Stores Operations," 364
King, B. J., address, "Concrete Repair by Epoxy Injection," 435

— L —

Lathrop, R. A., report, "Computer Usage in Southern Pacific's Engineering Department," 368
Lawson, E. C., address, "The Reading Company's Foreman's Training Course," 531
Locomotive sanding facilities, 169

— M —

Maintenance of way and structures gangs, sanitation requirements for portable housing units, 347
Maintenance of Way Work Equipment, committee report, 353
—selection of engines for, 354
Maynard, A. L., address, "Use of Track Analyzer Car Data in Inspection of Track and Maintenance Planning," 573
McCue, P. J., address, "Status Report on the National Rail–Highway Crossing Program," 504
McKay, Paul, memoir, 281
McLean, L. A., address, "Truck Hunting—A Cause and Effect of Component Wear in Freight Cars," 687

— N —

New York City Transit Authority, stores operations, 364

— O —

Office procedures, bibliography, 261
Officers, election (see Election of officers)

— P —

Peckover, F. L., address, "Treatment of Rock Falls on Railway Lines," 471
Pollution control, air, FRA (OSHA) environmental controls, 344
—land, disposal of solid wastes, 342
—noise, FRA (OSHA) environmental controls, 344
Price, B. H., address, "FRA, D&RGW, B&LE Joint Study of Track Geometry and Track Degradations," 554

— R —

Rail, committee report, 405
—alloy steel, chromium and manganese vanadium, tests of, 65
—continuous welded (see Continuous welded rail)
—research and development, 65
—rolled and shipped by weight and sections in 1972, 407
—shipped to North American railroads by weight and section in 1973, 408
—standard carbon and various wear-resistant, summary of performance of on Chessie System, 99
Rail sections, evolution of, 653
Rail steel, what is being done relative to this material today, 653
Reading Company, foreman's training course, 531
Regional Meeting, Kansas City, Mo., address, "Concrete Repair by Epoxy Injection," by B. J. King, 435
—address, "New Vertical Lift Bridge Over Chicago's Calumet River," by R. F. Beck, 432
—address, "Roadbed Stabilization—Various Methods," by J. R. Farris, 419
—addresses, "A Planning, Scheduling and Reporting System for MW&S Basic Force," by R. G. Brohaugh and D. D. Thomas, 437

Roadbed, maintenance of, 282
Roadbed stabilization, various methods, 419
Roadmasters, training courses for on Canadian National Railways, 536
Roadway and Ballast, committee report, 279
Rock falls, on railway lines, treatment of, 471

— S —

Sanding facilities, locomotive, Manual recommendations, 169
Scales, railroad, past, present and future applications, 523
—Special Committee on, report, 415
Schoeneberg, K. W., address, "Evolution of Rail Steel and What Is Being Done Relative to This Material Today," 653
—report, "Metallurgical Examination and Physical Test Results of Chromium and Manganese–Vanadium Alloy Rail Steel Investigation," 65
—report, "Summary of Performance of Standard-Carbon and Various Wear-Resistant Rails in Test Curves on Chessie System," 99
Signals, effect of railroad electrification on, 384
Southern Pacific Transportation Company, computer usage in engineering department, 368
Stafseth, H. E., address, "Status Report on the National Rail–Highway Crossing Program from a Highway Viewpoint," 509
Stations, railway passenger, design criteria for, Manual recommendations, 185
Steel Structures, committee report, 351
Systems Engineering, committee report, 363

— T —

Technical Conference (see Annual Technical Conference)
Termite control, investigation of wood preservatives for, 1
Thomas, D. D., address, "A Planning, Scheduling and Reporting System for MW&S Basic Force," 437
Ties, concrete, specifications for, Manual recommendations, 238
Ties, wood, annual renewal statistics, 55
Ties and Wood Preservation, committee report, 417
Timber Structures, committee report, 315
Timbers, bridge, evaluation of various sizes, 317
Track, committee report, 409
Track foremen, training course for on Reading Company, 531
Track geometry cars, management uses, 561
—use of in FRA, D&RGW, B&LE joint study, 554
—use of in inspection of track and maintenance planning, 573
Track geometry, joint study of by FRA, D&RGW and B&LE, 554
Tracks, specifications for construction of in a paved area, Manual recommendations, 221
Training courses, for track foremen on Reading Company, 531
—for roadmasters on Canadian National Railways, 536
Transportation Research Board, organization and functions, 465
Treasurer, report of, 703
Trestles (see Bridges)
Truck hunting—a cause and effect of component wear in freight cars, 687
Turnout design, 410

— U —

United States Railway Association, engineering systems approach to study for, 576

— V —

Valuation, current developments in connection with bodies and courts, 264
Vegetation control, Manual recommendations, 145

— W —

Wallace, J. F., report, "Fracture Mechanics and Plane Strain Toughness of Cast Steels," 665
Waterproofing, asphaltic panels, Manual recommendations, 217
Way, G. H., address, "Heavy Cars—What Are The Issues?", 616
Wieser, P. F., report, "Fracture Mechanics and Plane Strain Fracture Toughness of Cast Steels," 665
Wilbur, O. G., memoir, 300
Wood preservation, decay and termite control investigation, 1

— Y —

Yards, classification, computer applications to, 272
—hump, design criteria for design of car rollability, 268
Yards and Terminals, committee report, 267

DIRECTORY
CONSULTING ENGINEERS

FRANK R. WOOLFORD

Engineering Consultant—Railroads

24 Josepha Ave.
San Francisco, Ca. 94132
(415) 587–1569

246 Seadrift Rd.
Stinson Beach, Ca. 94970
(415) 868–1555

Westenhoff & Novick, Inc.
Consulting Engineers

Civil—Mechanical—Electrical
Fixed & Movable Bridges
Soils, Foundations, Buildings
Structural & Underwater Investigations
Planning, Feasibility, Design, Inspection

222 W. Adams St., Chicago, Ill. 60606

New York Washington Panama

HAZELET & ERDAL

Consulting Engineers

Design Investigations Reports
Fixed and Movable Bridges

150 So. Wacker Dr., Chicago, Ill. 60606
Louisville Cincinnati Washington

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF

Feasibility studies and design services for

Terminals	Bus and rail transit
Parking	Regional and urban planning
Tunnels	Soils and foundations
Utilities	Environmental impact studies
Structures	

Offices in 29 cities 816 474-4900
1805 Grand Ave., Kansas City, Mo. 64108

MODJESKI AND MASTERS
Consulting Engineers

Design, Inspection of Construction & Inspection of Physical Condition of Fixed & Movable Railroad Bridges

P.O. Box 2345, Harrisburg, Pa. 17105
1055 St. Charles Ave., New Orleans, La.

CLARK, DIETZ AND ASSOCIATES–ENGINEERS, INC.
Consulting Engineers

Bridges Structures, Foundations, Industrial Wastes and Railroad Relocation

211 No. Race St., Urbana, Ill.

Sanford, Fla. Memphis, Tenn.
Jackson, Miss. St. Louis, Mo.
Chicago, Ill.

Engineers

Designers Planners

**PARSONS
BRINCKERHOFF
QUADE
DOUGLAS**

Route Location, Shop Facilities, Container/Bulk Cargo, Handling Utilities, Bridges, Tunnels, Evaluations, Appraisals, Supervision

ONE PENN PLAZA, NEW YORK, NY 10001

Boston • Denver • Honolulu
San Francisco • Trenton

HARDESTY & HANOVER

Consulting Engineers

**TRANSPORTATION
ENGINEERING**

Highways • Railways
Bridges—Fixed and Movable
Design • Resident Inspection
Studies • Appraisals

101 Park Ave., New York, N. Y. 10017

THOMAS K. DYER, INC.

Consulting Engineers

**Railroads—Transit Systems
Track, Signals, Structures**

**Investigations and Feasibility Reports
Planning, Design, Contract Documents**

**1762 Massachusetts Avenue
Lexington, Mass. 02173**

DCO The De Leuw, Cather Organization

CONSULTING ENGINEERS

165 W. WACKER DRIVE • CHICAGO 60601

SUBWAYS • RAILROADS • PUBLIC TRANSIT
TRAFFIC • PARKING • HIGHWAYS
BRIDGES • PORT DEVELOPMENT • AIRPORTS
COMMUNITY PLANNING • URBAN RENEWAL
MUNICIPAL WORKS • INDUSTRIAL BUILDINGS
ENVIRONMENTAL SCIENCE AND ENGINEERING

ATLANTA • BOSTON • BUFFALO • NEWARK • NEW YORK
OKLAHOMA CITY • PHILADELPHIA • SAN FRANCISCO • SEATTLE
WASHINGTON, D.C. • BANGKOK • BEIRUT • SYDNEY

IECO

RAILROAD
DESIGN & ELECTRIFICATION

*Planning • Design
Construction Management*

**INTERNATIONAL ENGINEERING
COMPANY, INC.**

220 MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94104

**RILEY, PARK, HAYDEN &
ASSOCIATES, INC.**

Consulting Engineers

Survey Services, Photogrammetry, General Civil, Bridges, Railroads & Industrial Park Design.

**136 Marietta St., N. W.
Atlanta, Georgia 30303**
(404) 577-5600

R.W. BOOKER
& ASSOCIATES, INC.

ENGINEERS ARCHITECTS PLANNERS

1139 OLIVE ST. ST. LOUIS, MISSOURI 63101
LEXINGTON, KENTUCKY FORT WORTH, TEXAS

---

par PORTER AND RIPA ASSOCIATES, INC.

ENGINEERING · PLANNING · ARCHITECTURE

Design · Inspections · Reports
Planning · Structures
Environmental Studies

200 Madison Avenue, Morristown, New Jersey 07960

SVERDRUP & PARCEL AND ASSOCIATES, INC.
800 No. Twelfth Blvd. • St. Louis, Mo. 63101

Boston • Charleston • Gainesville • Jacksonville
Nashville • New York • Phoenix • San Francisco
Seattle • Silver Spring • Washington, D.C.

SVERDRUP & PARCEL

- design
- planning
- construction management

CONSULTING ENGINEERS

SOROS ASSOCIATES
Consulting Engineers

Transfer Terminals & Ports For Dry Bulks,
Liquids & Containers—Waterfront Structures
Materials Handling Systems

575 Lexington Ave.
New York, N. Y. 10022
(212) 421–0400

Rio de Janeiro Santiago, Chile
Sydney, Australia

RALPH WHITEHEAD
& ASSOCIATES
Consulting Engineers

Bridges, Buildings, Highways,
Railroads, Airports
1945 RANDOLPH ROAD
CHARLOTTE, NORTH CAROLINA 28207

AJH INC
A. J. HENDRY, INC.
CONSULTING ENGINEERS

SIGNALS • COMMUNICATIONS • AUTOMATION • ELECTRIFICATION
RAILROADS • RAIL TRANSIT

SUITE 810 OSBORN BUILDING
ST. PAUL, MINNESOTA 55102
(612) 222 2787

SPAULDING ENGINEERING CO.

CONSULTING ENGINEERS
MEMBER
AMERICAN CONSULTING ENGINEERS COUNCIL

1821 UNIVERSITY AVENUE
ST. PAUL, MINNESOTA 55104
PHONE 612/644-5676

TURNER ENGINEERING COMPANY

(SAWYER–PIEPMEIER)

RAILROAD ENGINEERING

306 GAY ST.
NASHVILLE, TENNESSEE 37201
615–244–2144
ALBANY, NY 518–456–1994

BAKKE & KOPP, INC.

Consulting Engineers

RAILWAY AND HIGHWAY BRIDGES

SPECIAL AND HEAVY STRUCTURES

INVESTIGATIONS AND REPORTS

4915 W. 35th St. Minneapolis, MN 55416
(612) 920–9383

MORE TON MILES
of SERVICE
and LESS MAINTENANCE
with

SPENO
SERVICES

BALLAST
CLEANING

RAIL
GRINDING

Discover how you can get more ton miles of service at less maintenance cost by using Speno Ballast Cleaning and Rail Grinding

THROUGHOUT THE CONTINENT

"Just Ask the Railroads That Use Our Services"

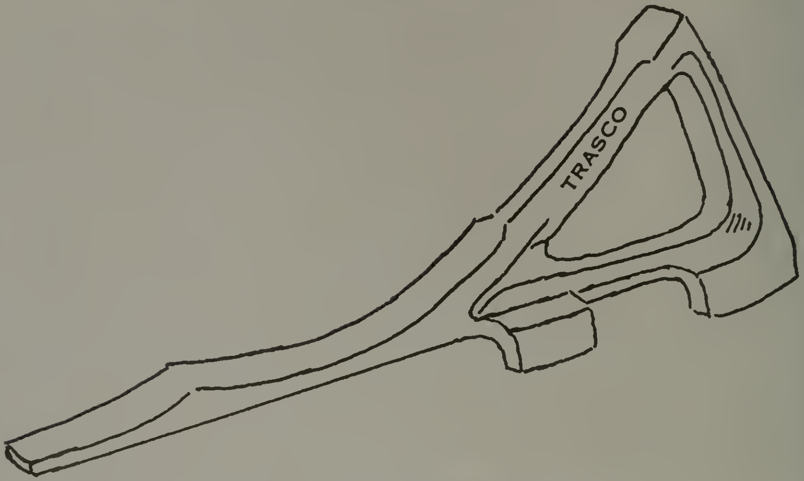
FRANK SPENO RAILROAD BALLAST CLEANING COMPANY, INC.
306 North Cayuga St., Ithaca, New York 14850
Clark Street, Box 219, East Syracuse, New York 13057

SPENO INTERNATIONAL, S.A.
22 Parc Chateau Banquet, Geneva, Switzerland
(For Rail Grinding Outside the North American Continent)

RPI

IEC-HOLDEN, LTD.
8180 Cote de Liesse Road
Montreal, Canada H4T1G8

TRASCO Track Skates



Preferred by skatemen
Light
Tough
Balanced hand hold
No curl tongue

TRACK SPECIALTIES
COMPANY
Box 729 Westport, Conn.